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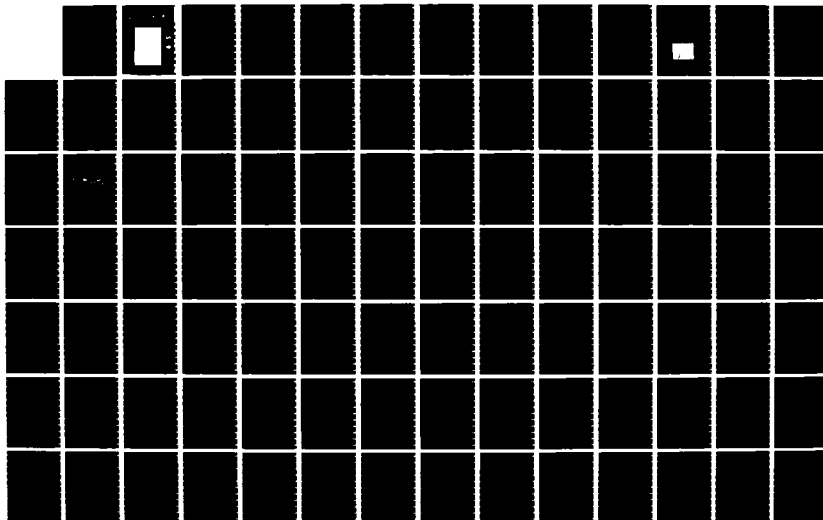
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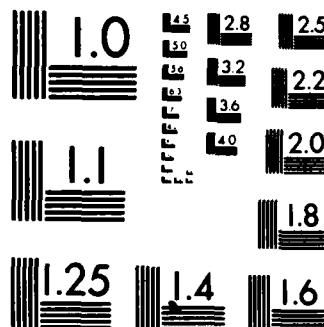
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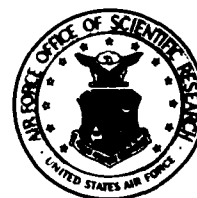
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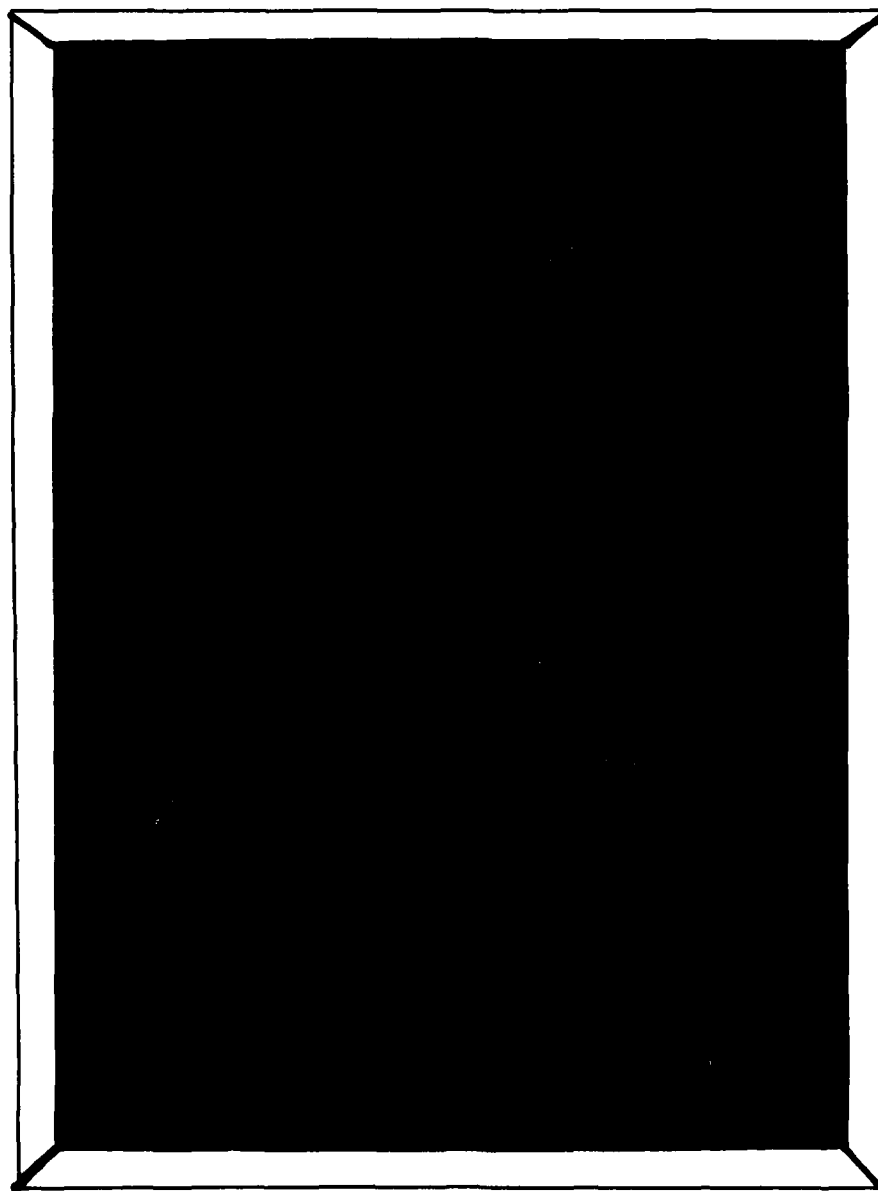
VOL. 11, NO. 2

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SCIENTIFIC BULLETIN



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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) ONRFE Vol 11, No 2			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION Office of Naval Research/Air Force Office of Scientific Res		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION		
6c. ADDRESS (City, State, and ZIP Code) Liaison Office, Far East APO San Francisco 96503-0007			7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO	PROJECT NO	TASK NO
			WORK UNIT ACCESSION NO		
11. TITLE (Include Security Classification) ONR FAR EAST SCIENTIFIC BULLETIN					
12. PERSONAL AUTHOR(S) George B. Wright, Director; Mary Lou Moore, Editor					
13a. TYPE OF REPORT		13b. TIME COVERED FROM TO		14. DATE OF REPORT (Year, Month, Day) April-June 1986	
15. PAGE COUNT					
16. SUPPLEMENTARY NOTATION ISSN: 0271-7077					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	III-V compound semiconductors Heterointerface field		
			MOCVD technology effect transistor (HEMT)		
			Japan R&D activities Japan		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East and the Air Force Office of Scientific Research with certain reports also being contributed by visiting state-side scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.</p> <p>Subscription requests to the Scientific Bulletin should be directed to the Superintendent of Documents, Attn: Subscription, Government Printing Office, Washington, D. C. 20402. The annual subscription charge is: domestic \$13.00; foreign, \$16.25. Cost for a single copy is: domestic, \$4.50; foreign, \$5.65.</p>					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL

18. Subject Terms (Key Words) continued

Japan Society of Applied Physics
Meteorological Research Institute
Tsukuba Science City
Geophysics
Oceanographics
Marine research
Ocean Research Institute
University of Tokyo
Rainfall variability
Air pollution
Republic of the Philippines
Agriculture
Fisheries
PCARRD
Natural resources
Optoelectronics
Compound semiconductor technology
People's Republic of China
Integrated optics
Japan Fine Ceramics Center
Ceramics Society of Japan
Ministry of Education, Science
and Culture
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Synchrotron radiation research
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Permanent magnet undulators
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Bulk wave resonators
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Frequency control devices
Information technology
Measurement science
Australia
Instrumentation engineering
Japan Key Technology Center
Government-sponsored research
Ministry of International Trade and Industry
Ministry of Posts and Telecommunications
Civilian enterprises
English language
Information sources
Japan
High technology
Research services
Manufacturing

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sources (wiggler and undulator magnets) and storage rings optimized for their use.

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Cover: Australian aborigine figure carvings--courtesy of the Information Attaché,
Australian Embassy, Tokyo, Japan.

INVERSION-BASE BIPOLAR TRANSISTOR

At the recent Japan Society of Applied Physics meeting, which was held 1-4 April 1986 at University of Nihon, the Electrotechnical Laboratory reported the fabrication of a new transistor called an inversion-base bipolar transistor (IBT), which, they believe, could be ten times faster than conventional GaAs heterobipolar transistors.

The new transistor has no doped base layer between the collector and emitter. Instead, it utilizes an extremely thin "two-dimension hole gas" layer which is generated as a result of the inversion of the interface layer between the AlAs barrier layer and n-GaAs collector layer interface. The inversion of the interface layer was induced by the application of the negative potential to the base and emitter electrodes. The hole gas lies between the AlAs barrier and collector.

The cross section of the IBT is shown in Figure 1. It consists of an emitter layer-n GaAs (Si-doped, $1 \times 10^{16}/\text{cm}^3$, $1.5 \mu\text{m}$) grown by MBE. By using the self-alignment technique, the p⁺-GaAs region was formed by Mg ion implantation outside the base region. The sample was flash annealed at 800°C for 30 seconds. The energy diagram shows $\Delta E_c=0.2$ eV and $\Delta E_v=0.55$ eV. When the voltage is applied to the emitter, electrons are tunneled through the AlAs barrier from the emitter to the collector. Because of the large valance band discontinuity, the holes generated in the inversion layer do not spill into the emitter region. In Figure 2, the transistor characteristics for emitter-common at 77 K is shown. The current amplification factor β of 3.8 was obtained. This is expected to increase further by reduction of the AlAs barrier. The emitter-base voltage of more than $V_{BE}=1.8$ V was necessary to obtain the transistor characteristics at 77 K. This emitter-base voltage of $V_{BE}=1.8$ V is the bias necessary to invert the AlAs/n⁻GaAs interface and induce the two-dimensional hole gas. The emitter area of present devices are about $50 \times 50 \mu\text{m}$.

Yoon Soo Park
ONRFE/AFOSRFE

USE OF THE LDD STRUCTURE IN GaAs MESFETs

In order to prevent the short channel effect in GaAs MESFETs, several electronic device houses in Japan are applying the lightly doped drain (LDD) structure often employed in Si LSIs. At the recent spring meeting of the Japan Society of Applied Physics, 1-4 April 1986, Hitachi reported, for example, the formation of the lightly doped region n' by implantation through a SiO₂ or SiO₂/AlN cap.

In two processes employed, they adopted the use of 0.3- μm -thick SiO₂ walls to perform implantation for n-layer formations. Implantations of 40 keV-- $8 \times 10^{12} \text{ cm}^{-2}$ for the n' layer, and the 150 keV-- $2 \times 10^{13} \text{ cm}^{-2}$ for the n⁺ layer with the 800°C--30 s anneal were carried out.

By employing the LDD technique, they were able to obtain the threshold voltage variation of 0.1-0.2 V for the gate lengths of 0.5-1 μm . For the devices of $L_g=0.5 \mu\text{m}$ and $W_g=10 \mu\text{m}$, they obtained $G_m=320 \text{ mS/mm}$ and $R_s=0.7-0.8 \text{ ohms/mm}$.

NEC Corporation also reported the formation of the LDD region by implantation of

50 keV $^{28}\text{Si}^+$ ions in conjunction with the use of the sidewall-assisted self-alignment technology (SWAT) and a two-layer WSi_x -W gate. The n' implantation was performed in the 0.3 μm spacing between the n^+ contact regions and the gate formed by SWAT using SiO_2 .

For the dose of $n' \sim 7 \times 10^{12} \text{ cm}^{-2}$, they obtained a large K value of 250 mS/V mm. The gate sustaining voltage ($-BV_{\text{GD}}$) is seen to decrease as the n' dose is increased. With $L_g = 0.8 \mu\text{m}$ devices, $G_m = 250 \text{ mS/mm}$, $V_T = 0.1 \text{ V}$ and $\sigma V_T = 35 \text{ mV}$ were obtained.

Yoon Soo Park
ONRFE/AFOSRFE

ATOMIC LAYER EPITAXY OF GaAs BY SL-MOVPE

The Laser Science Group headed by Professor S. Namba at Rikagaku Kenkyusho (the Institute of Physical and Chemical Research, *RIKEN*) has announced the growth of an atomic layer of GaAs by a switching laser metal-organic vapor phase epitaxy technique (SL-MOVPE).

In the SL-MOVPE, TMG and AsH_3 gas streams are alternatively introduced into the growth chamber where the substrate is maintained at 450°C. To produce an atomic layer of gallium, the laser is turned on to irradiate the substrate surface during the exposure of the substrate to TMG gases. By synchronizing the introduction of the TMG and AsH_3 streams with the irradiation of the laser beam, alternating layers of Ga and As atoms are formed. At present, they have produced an ALE sample of 1 mm^2 in area; however, they are attempting to grow larger samples by scanning the laser beam.

Yoon Soo Park
ONRFE/AFOSRFE

EXTREMELY LOW-NOISE HEMTs FABRICATED ON MOCVD EPI-WAFERS

At the National Convention of the Institute of Electronics and Communication Engineers of Japan (IECEJ), which was held on 23-26 March 1986 at Niigata University, workers at Toshiba Corporation reported the fabricating of an extremely low-noise HEMT using epitaxial layers grown by MOCVD.

The structure of the low-noise HEMT is similar to that of the MBE grown HEMT reported previously by Toshiba workers. A 0.25- μm -gate HEMT was fabricated on the epitaxial layer structure consisting of a Si GaAs substrate, a 0.5 μm , undoped GaAs buffer layer, a 300 Å, $n\text{-Al}_{0.3}\text{Ga}_{0.7}\text{As}$ layer and a 600 Å $n\text{-GaAs}$. The epi-layers were grown using TEG, TEA, and AsH_3 under atmospheric pressure.

At room temperature, the HEMT provided a minimum noise figure of 0.75 dB with an associated gain of 11.1 dB at 12 GHz and a minimum noise figure of 1.2 dB with an associated gain of 7.9 dB at 18 GHz. These are the lowest figures ever reported for low-noise HEMTs fabricated on MOCVD grown epitaxial layers and close to those obtained on MBE wafers.

Yoon Soo Park
ONRFE/AFOSRFE

ROOM TEMPERATURE CW OPERATION OF InGaAlP VISIBLE LASERS

Toshiba workers have also reported the fabrication of a cw transverse mode stabilized InGaP/InGaAlP self-aligned DH laser diode emitting at 680 nm at room temperature using MOCVD epi-layers. Transverse mode stabilization was achieved by forming the ridge stripe.

The epitaxial layers were grown on a (100) oriented Si-doped GaAs substrate by two-step selective growth at 700°C using a vertical, low-pressure (~ 75 Torr) MOCVD reactor. The laser structure as shown in the Figure 3 consists of a

- Se-doped n-GaAs buffer layer ($0.2\text{ }\mu\text{m}$, $1 \times 10^{18}\text{ cm}^{-3}$),
- Se-doped n- $\text{In}_{0.5}\text{Ga}_{0.25}\text{Al}_{0.25}\text{P}$ cladding layer ($1.0\text{ }\mu\text{m}$, $1 \times 10^{18}\text{ cm}^{-3}$),
- undoped, n- $\text{In}_{0.5}\text{Ga}_{0.5}\text{P}$ active layer layer ($0.15\text{ }\mu\text{m}$),
- Zn-doped p- $\text{In}_{0.5}\text{Ga}_{0.25}\text{Al}_{0.25}\text{P}$ cladding layer ($1.0\text{ }\mu\text{m}$, $7 \times 10^{17}\text{ cm}^{-3}$), and
- Zn-doped p-GaAs contact layer ($0.5\text{ }\mu\text{m}$, $2 \times 10^{18}\text{ cm}^{-3}$).

After the P-GaAs contact layer growth, a sputtered SiO_2 layer was deposited and $5\text{-}\mu\text{m}$ -wide ridge stripes in the (011) direction were formed by chemical etching. Subsequently, the selective growth of a Se-doped n-GaAs ($1.0\text{ }\mu\text{m}$, $1 \times 10^{18}\text{ cm}^{-3}$) was performed.

The fabricated DH diode showed a cw operation at room temperature at a threshold current of 96 mA and lased at 680 nm with single longitudinal and fundamental transverse modes. They claim that this is the first transverse mode stabilized InGaAlP laser diode ever fabricated by MOCVD.

Yoon Soo Park
ONRFE/AFOSRFE

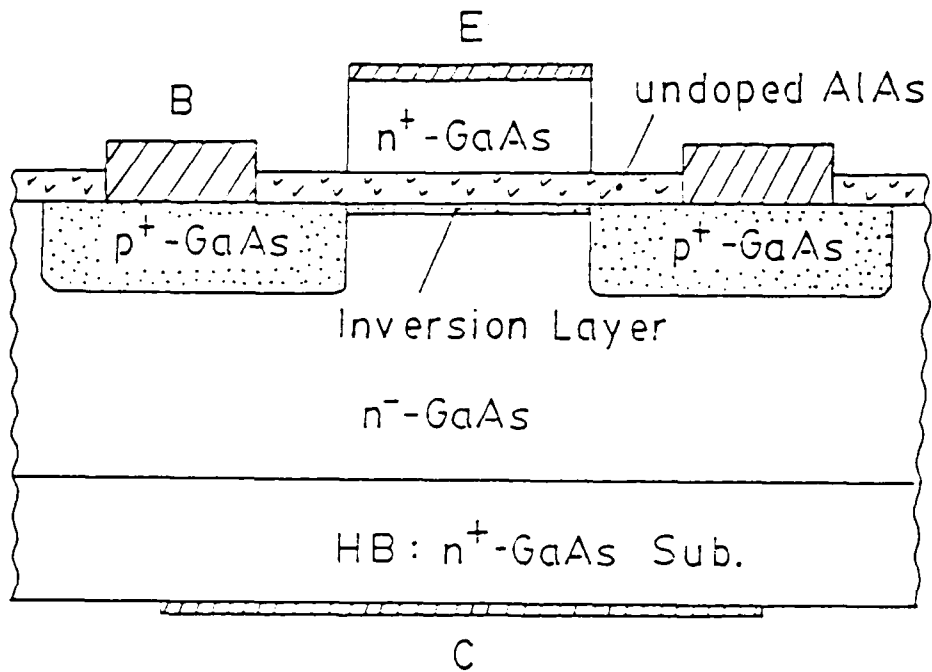


Figure 1. GaAs IBT: Schematic Structure of GaAs Inversion-Base Bipolar Transistor.

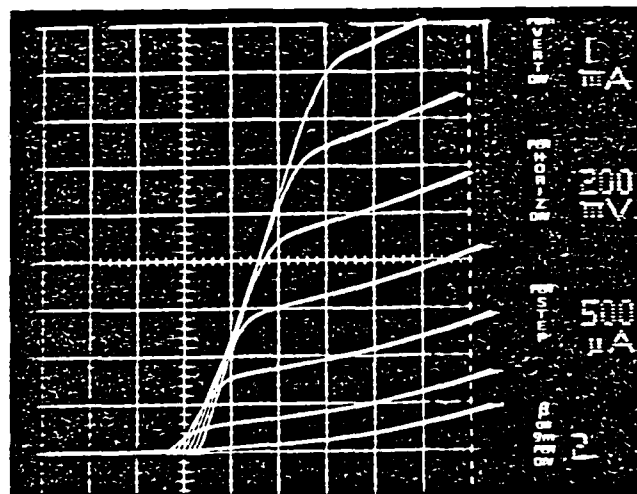


Figure 2. Transistor Characteristics of GaAs IBT at 77 K for Emitter-common Circuit.

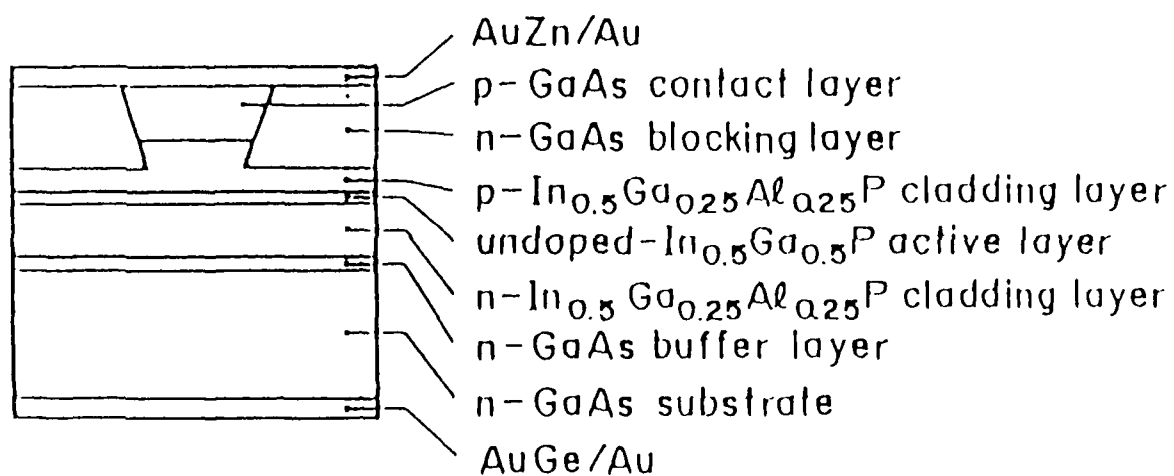


Figure 3. A Schematic Cross Sectional View of the Laser Structure.

JAPANESE ACCOMPLISHMENTS IN MOCVD GROWTH OF III-V COMPOUND SEMICONDUCTORS

Yoon Soo Park

INTRODUCTION

In recent years, the growth technologies of ultrathin multilayer structures such as molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) has progressed rapidly to meet the challenge of compound semiconductor technology. In particular, with recent demonstrations of superlattices, quantum wells, lasers, FETs, HEMTs, hot electron transistors by MOCVD, MOCVD has now become a viable tool for production of potential electron devices as an alternative to MBE. By using MOCVD, it is now possible to grow high-device quality layers comparable to those grown by MBE in terms of purity, uniformity in composition and thickness, interface and surface quality, and heterojunction abruptness.

For the past few years, Japanese R and D activities in MOCVD technology has expanded at a rapid pace. It has been the general consensus that the U.S. is leading Japan in MOCVD technology. If there is a gap, however, that gap has apparently narrowed. Recent accomplishments of Japanese workers in MOCVD technology areas clearly demonstrates the Japanese capability of catching-up with Western countries and their intent and seriousness in applying MOCVD technology for the production of marketable devices. Examples of their competitiveness can be seen in the recent announcement of the commercialization of a HIFET (heterointerface field effect transistor, commonly known as a HEMT) by Sony Corporation, GaAs/AlGaAs visible lasers by Sony and Mitsubishi Electric, and LEDs for short distance optical-fiber communications by Toshiba Corporation. One of the potential advantages of MOCVD technology is the large-area growth capacity is utilized for low-cost production of practical devices.

Increased R and D activities in MOCVD technology in Japan is also apparent by the increasing number of papers presented at the annual spring and fall meetings of the Japan Society of Applied Physics (JSAP). For example, there were about 50 papers dealing with MOCVD-related subjects of III-V compound semiconductors in the 1983 fall meeting of the JSAP, while there was approximately a twofold increase in the number of papers presented at the 1986 spring meeting.

In this report, some observations on recent research and development activities and accomplishments in MOCVD technology in Japan made by the author will be discussed.

Some Japanese achievements in MOCVD technology include:

- attainment of high purity and high mobility GaAs at Toshiba,
- growth of AlAs/GaAs monolayer-scale superlattices at Sony,
- attainment of monolayer growth by flow rate modulation epitaxy at Nippon Telegraph and Telephone Corporation (NTT),
- achievement of a high 2DEG mobility of $4.45 \times 10^5 \text{ cm}^2/\text{V.s}$ at 2 K in the HEMT structure at NTT,

- demonstration of a HEMT with a high g_m of 350 mS/mm at NTT,
- fabrication of extremely low-noise HEMTs at Toshiba,
- fabrication of a GaAs power FET from GaAs on Si at Oki Electric,
- commercialization of a HEMT by Sony,
- commercialization of lasers by Sony and Mitsubishi Electric and LEDs by Toshiba,
- growth of a high-purity InP with a carrier concentration of $5 \times 10^{14}/\text{cm}^3$ and a mobility of $1.07 \times 10^5 \text{ cm}^2/\text{V.s}$ at 77 K by NTT.

Some of the MOCVD growth activities at Toshiba Corporation, [the *Scientific Bulletin*, 10, (4) 127, (1986)] and at the Sony Research Center [the *Scientific Bulletin* 11, (4) 74, (1986)] have already been reviewed by the author. In Appendix I, key players in MOCVD technologies in Japanese universities are summarized.

RESEARCH AND ACCOMPLISHMENTS

- High-purity GaAs Materials

Toshiba Corporation: The Toshiba Research and Development Center has been involved with the development of the MOCVD technique to improve the quality of GaAs and GaAlAs for device applications. They have been extensively investigating the optimization processes for obtaining high quality GaAs and GaAlAs in relation to the starting materials, substrate orientations, growth conditions and impurity doping.

A vertical rf-heated reactor is exclusively employed at Toshiba. Epitaxial layers are grown under either atmospheric pressure or low pressure using source materials of TMG, TMA, and AsH_3 . Dimethylzinc (DEZ) and H_2Se are often used for p- and n-type dopants, respectively. The layers are normally grown at $\sim 750^\circ\text{C}$.

By careful selection of both TMG and AsH_3 sources, they have grown a GaAs layer having a 77 K mobility of $139,000 \text{ cm}^2/\text{V.s}$ with an electron concentration of $3.7 \times 10^{14}/\text{cm}^3$ under atmospheric pressure. Though the mobility value is still lower than those obtained for LPE and VPE grown layers, this is one of the best values ever reported for MOCVD grown layers.

- Monolayer Growth

The Sony Research Center has recently grown AlAs/GaAs monolayer scale superlattices by atmospheric pressure MOCVD.

Ultrathin superlattice layers of $(\text{GaAs})_n(\text{AlAs})_n$ approaching $n=2$ have been grown under atmospheric pressure at 750°C and at the growth rate of 240 Å/min in the total gas flow of 11 l/m. In the system used for superlattice growth, the velocity of gas is achieved up to 1 m/s. The high velocity is obtained by the combination of a very high gas flow rate and a thin reactor tube.

Recently, they have been analyzing the heterointerface structure of a $(\text{GaAs})_2(\text{AlAs})_2$ superlattice by a cross sectional TEM image, a lattice image, and a TED

pattern. In these analyses, no defects or disordering in superlattice layers have been observed. GaAs/AlAs transition had well-defined boundaries and took place within one atomic layer in the heterointerface.

Unlike MBE-grown superlattice structures, no interface broadening has been observed even though the superlattice structures were grown at high temperatures of 750-880°C in MOCVD.

The Musashino Electrical Communication Laboratory, NTT, reported the successful growth of GaAs monolayers by the atomic layer epitaxy (ALE) technique at the 12th International Symposium on GaAs and Related Compounds held in Karuizawa, 23-26 September 1985. The ALE technique involves the repetition of alternate injections of reactant gas molecules onto the growth substrates.

NTT calls the technique, the flow-rate modulation epitaxy (FME) method. In the FME method, gas sources of triethylgallium (TEG) and arsine (AsH_3) are alternatively introduced by a hydrogen carrier gas. The period of 1 sec was used for each cycle. However, during the TEG flow period, a very small amount of the AsH_3 flow was sustained instead of interrupting the AsH_3 flow as was practiced by other workers. They believe that this continuous AsH_3 flow during the TEG flow period reduces the formation rate of arsenic vacancies.

The layers growth by FME at 550°C exhibit the carrier concentration of $7.6 \times 10^{18} \text{ cm}^{-3}$ and the mobility of $41,800 \text{ cm}^2/\text{V.s}$.

The first report of the successful growth of GaAs by ALE was made by Dr. Junichi Nishizawa of the Semiconductor Research Institute at Sendai in August of 1984. At the time of the first announcement by Nishizawa, many people were skeptical about the technique, particularly in the growth of GaAs material systems. Latest activities, however, indicate the technique is catching on in Japan and being reexamined. At the 17th Conference on Solid State Devices and Materials held in Tokyo, 25-27 August 1985, researchers at Tokai University and the Electrotechnical Laboratory reported atomic layer epitaxy growth of ZnSe and ZnTe single crystalline films. There was also a report on the ALE growth of GaAs by hydride vapor phase epitaxy by NEC researchers in Karuizawa.

- High g_m MOCVD Grown 2DEG FETs

The Musashino Electrical Communication Laboratory, NTT, has reported the fabrication of high transconductance ($g_m \sim 330 \text{ mS/mm}$) 2DEG AlGaAs/GaAs FETs by low pressure ($\sim 80 \text{ Torr}$) MOCVD.

They attribute this high g_m to a high 2DEG mobility in the structure resulting from the use of triethylaluminum (TMA) and triethylgallium (TEG) instead of commonly employed trimethylaluminum (TMA) and trimethylgallium (TMG), in their low pressure MOCVD growth system. At 77 K the electron mobility and the sheet electron concentration of the 2DEG structure were found to be $27,000 \text{ cm}^2/\text{V.s}$ and $1.3 \times 10^{12} \text{ cm}^{-2}$, respectively. Previously, they reported a 2DEG mobility of $450,000 \text{ cm}^2/\text{V.s}$ at 2 K. Though there had been reports of the fabrication of 2DEG FETs by MOCVD, the g_m of the fabricated devices were lower than that of the MBE grown structures. It is believed that the use of TMA and TMG results in the incorporation of carbon impurities into AlGaAs, thus lowering the 2DEG mobility in the structure.

- HEMTs

Toshiba Corporation reported the fabrication of an extremely low-noise HEMT using epitaxial layers grown by MOCVD.

The structure of the low-noise HEMT is similar to that of the MBE-grown HEMT reported previously by Toshiba workers. A 0.25- μm -gate HEMT was fabricated on the epitaxial layer structure consisting of a Si GaAs substrate, a 0.5 μm , undoped GaAs buffer layer, a 300 Å, n-Al_{0.3}Ga_{0.7}As layer and a 600 Å n-GaAs. The epi-layers were grown using TEG, TEA, and AsH₃ under atmospheric pressure.

At room temperature, the HEMT provided a minimum noise figure of 0.75 dB with an associated gain of 11.1 dB at 12 GHz and a minimum noise figure of 1.2 dB with an associated gain of 7.9 dB at 18 GHz. These are the lowest figures ever reported for low-noise HEMTs fabricated on MOCVD grown epitaxial layers and close to those obtained on MBE wafers.

The Sony Research Center has also demonstrated the unique capability of advanced MOCVD technology by fabricating low-noise HEMTs with GaAlAs/GaAs heterostructures. Attainment of such devices is due to both the high quality of crystal growth and the abrupt heterointerfaces obtained by the MOCVD process.

Sony's HEMT consists of the epitaxial layers of an 0.50 μm undoped GaAs layer and 0.05 μm n-Ga_{0.7}Al_{0.3}As layer grown under atmospheric pressure at 720°C at the growth rate of 250 Å/min. In order to increase the sheet carrier density of the two-dimensional electron gas, no spacer layer is employed. The n-GaAlAs layer is doped to $1.6 \times 10^{18} \text{ cm}^{-3}$. Hall mobilities of 6230 at 300 K and 38,000 $\text{cm}^2/\text{V.s}$ at 77 K were obtained. With a 100 Å, spacer, mobilities of 8100 and 148,000 $\text{cm}^2/\text{V.s}$ were obtained at 300 and 77 K, respectively. These values are comparable to those obtained in MBE grown layers.

The device with the 3500 Å Al gate of 0.8- μm -length and 200- μm -width was fabricated. The separation between the source and the drain is about 2 μm and AuGe/Ni is used for ohmic contacts. At 12 GHz, the HEMT exhibited the minimum noise figure of 1.47 dB with 9 dB associated gain. These results are comparable to microwave performances of GaAs MESFET.

- MESFETs

Oki Electric Industry Company, Ltd., the Research Laboratory has grown a high purity and high resistivity GaAs buffer layer on a Cr-doped HB semi-insulating GaAs substrate, which is suitable for direct ion implantation, by low pressure (~ 100 Torr) MOCVD. The GaAs layer grown at 640-710°C on a two-inch wafer exhibited an electron mobility of $1.0 \times 10^5 \text{ cm}^2/\text{V.s}$ with a carrier concentration of less than 10^{15} cm^{-3} at 77 K.

MESFETs were fabricated by the W-Al gate self-alignment process on an active layer formed by the ion implantation of ^{29}Si at an energy of 60 keV with a dose of $1.3 \times 10^{12} \text{ cm}^{-2}$. The self-aligned n^+ ion implantation was performed with a 100 keV, $1.5 \times 10^{13} \text{ cm}^{-2}$ ^{29}Si . The implanted layer was annealed at 800°C for 20 min with a SiO₂ cap. FETs with 1.5 μm gate length arrayed in a 4.8 mm x 5.6 mm pitch exhibited a threshold voltage standard deviation of 18.5 mV. This standard deviation of 18.5 mV is considered to be the best value ever reported within a two-inch wafer.

The MOCVD grown epitaxial buffer layer is shown to be a promising substrate suitable for GaAs LSI fabrication.

NEC Corporation, Second LSI Division has recently developed a sidewall assisted self-alignment GaAs MESFET with *selective MOCVD grown* n^+ contact regions. In their scheme, instead of producing n^+ contact regions by selective ion implantation as employed in the self-alignment GaAs processing technology, they formed n^+ regions on the ion implanted active layer in order to prevent short channel effects normally encountered due to lateral diffusion of the implanted n^+ impurities. In the fabrication of the MESFET, special care has been taken to achieve good n^+/n interface properties through the analysis of RIE-treated GaAs surfaces and growth-interrupted interfaces. Using the WSi_x refractory metal gate technology, they obtained a high g_m of 350 mS/mm at $V_{th} = -0.6$ V for the gate length of 0.3 μm .

Toshiba Corporation has also been evaluating the utility of the MOCVD technique for microwave device applications. They have reported, for example, the state-of-the-art half- and quarter-micron GaAs MESFETs and GaAs power MESFETs fabricated by MOCVD. They attribute their success to the availability of high-purity buffer layers grown by MOCVD [see *Scientific Bulletin*, 10, (4) 127, 1985].

- A half-micron low noise GaAs MESFET provided a noise figure of 1.3 dB with an associated gain of 11 dB at 8 GHz.
- A quarter-micron GaAs MESFET showed a noise figure of 1.75 dB with an associated gain of 8.5 dB at a drain current of 10 mA at 18 GHz.
- A power GaAs MESFET of a two-chip device having a gate width of 14.4 mm, for example, exhibited the power output of 4 W at 7.8 GHz with 3 dB gain and 12% power added efficiency.

- MOCVD Grown Lasers

The Sony Research Center recently, for the first time, has achieved room temperature cw operation of AlGaInP DH lasers from MOCVD grown layers. The planar stripe laser with a 10- μm -wide and 250- μm -long ion implanted stripe geometry emits at 671 nm under cw operation at 10°C at a threshold current of 160 mA. The cw operation is possible up to 23°C. The characteristic temperature T_0 was observed to be 155 K. They attribute this high characteristic temperature to a reduced thermal resistance of the device which has resulted from the addition of a dually-stacked cladding structure to a conventional double heterostructure. The thermal resistance of the laser was found to be 58°C/W, which was less than one-half the value of the conventional double heterostructure.

The epitaxial layers grown at 610°C under atmospheric pressure consists of six layers on a Si-doped GaAs substrate:

- p-GaAs cap layer ($p \sim 1 \times 10^{19} \text{ cm}^{-3}$, $d \sim 0.14 \mu m$),
- p- $Al_{0.76}Ga_{0.14}As$ second cladding layer ($p \sim 3 \times 10^{17} \text{ cm}^{-3}$, $d \sim 0.65 \mu m$),
- p- $Al_{0.26}Ga_{0.26}In_{0.48}P$ first cladding layer ($p \sim 6 \times 10^{17} \text{ cm}^{-3}$, $d \sim 0.33 \mu m$),
- undoped $Ga_{0.52}In_{0.48}P$ active layer ($d \sim 0.20 \mu m$),
- n- $Al_{0.26}Ga_{0.26}In_{0.48}P$ cladding layer ($n \sim 1 \times 10^{18} \text{ cm}^{-3}$, $d \sim 1.1 \mu m$), and
- n-GaAs buffer layer ($n \sim 4 \times 10^{18} \text{ cm}^{-3}$, $d \sim 0.14 \mu m$).

The combination of the first and second cladding layers is called the dually-stacked cladding structure (DSC).

With a mesa stripe laser structure, the maximum operating temperature was increased to 33°C. For a laser with a 6-μm-wide and 250-μm-long stripe geometry, the threshold current was reduced to ~100 mA and the thermal resistance of 49°C/W was obtained.

Toshiba Corporation has also reported the fabrication of a cw transverse mode stabilized InGaP/InGaAlP self-aligned DH laser diode emitting at 680 nm at room temperature using MOCVD epi-layers. Transverse mode stabilization was achieved by forming the ridge stripe.

The epitaxial layers were grown on a (100) oriented Si-doped GaAs substrate by two-step selective growth at 700°C using a vertical, low-pressure (~75 Torr) MOCVD reactor. The laser structure consists of a

- Se-doped n-GaAs buffer layer (0.2 μm, $1 \times 10^{18} \text{ cm}^{-3}$),
- Se-doped n-In_{0.5}Ga_{0.25}Al_{0.25}P cladding layer (1.0 μm, $1 \times 10^{18} \text{ cm}^{-3}$),
- undoped, n-In_{0.5}Ga_{0.5}P active layer layer (0.15 μm),
- Zn-doped p-In_{0.5}Ga_{0.25}Al_{0.25}P cladding layer (1.0 μm, $7 \times 10^{17} \text{ cm}^{-3}$),
- Zn-doped p-GaAs contact layer (0.5 μm, $2 \times 10^{18} \text{ cm}^{-3}$).

After the P-GaAs contact layer growth, a sputtered SiO₂ layer was deposited and 5-μm-wide ridge stripes in the [011] direction were formed by chemical etching. Subsequently, the selective growth of a Se-doped n-GaAs (1.0 μm, $1 \times 10^{18} \text{ cm}^{-3}$) was performed.

The fabricated DH diode showed a cw operation at room temperature at a threshold current of 96 mA and lased at 680 nm with single longitudinal and fundamental transverse modes. They claim that this is the first transverse mode stabilized InGaAlP laser diode ever fabricated by MOCVD.

. Tokyo Institute of Technology at Ookayama, the Suematsu Laboratory

Professor Yasuharu Suematsu, a world-renowned expert on semiconductor lasers, and his group have been actively engaged in research on optical communications, with particular emphasis on optical transmission lines, semiconductor lasers, and integration of optical circuits. His current research covers a wide range of topics:

- dynamic single mode lasers,
- property of semiconductor lasers,
- integrated lasers and optical integrated circuits,
- metal-insulator superlattice high speed electronic devices, and
- MOCVD growth of GaInAsP/InP.

One of his recent accomplishments is the demonstration of a cw room temperature 1.55 μm GaInAsP/InP buried heterostructure laser with a multi p-n current blocking grown entirely by low pressure (~76 Torr). The laser with a cavity of 2 μm width, 200 μm length operated at a threshold current of 48 mA.

DH layers consisting of a p-InP buffer layer (Zn-doped, 1 μm), an undoped GaInAsP

active layer ($0.13\text{ }\mu\text{m}$) and an n-InP cladding layer (Se-doped, $2\text{ }\mu\text{m}$) was grown at 640°C . After the growth, an active stripe width of $2\text{ }\mu\text{m}$ was formed by undercutting and mesa etching by use of a SiO_2 stripe. This SiO_2 stripe was also used for the selective regrowth of p-n multi layers for current confinement. A further reduction of threshold current can be obtained with further optimization of the technique employed here to form a narrow stripe by undercutting the mesa.

- Selective MOCVD Growth

A number of laboratories in Japan are involved with developing selective epitaxy technology for MOCVD for the fabrication of planar electronic optoelectronic devices and for monolithic device integration. For example, several laboratories have successfully fabricated GaAs/AlGaAs buried heterostructure (BH) lasers by selective MOCVD epitaxy, which provided good uniformity in terms of threshold and single-mode characteristics of the lasers in comparison with LPE.

Furukawa Electric Company, the Central Research Laboratory has, for example, applied a selective MOCVD growth to fabricate a planar BH laser diode. They first grew a GaAs/AlGaAs DH laser at atmospheric pressure and then applied the selective growth technique at low pressure to form a semi-insulating, AlGaAs buried layer. For the selective growth, a SiO_2 mask was employed to define a $8\text{ }\mu\text{m}$ stripe. The resistivity of the semi-insulating AlGaAs was more than $10^7\text{ }\Omega\cdot\text{cm}$ at the V/III ratio of 100. The diode operating at the threshold current of 20 mA lased at 879 nm continuously at room temperature.

The Tokyo Institute of Technology (TIT) at Nagatsuda, the Kukimoto Laboratory has recently demonstrated a selective area formation of semi-insulating GaAs by selectively irradiating the substrate with an ArF excimer laser during growth in a low-pressure MOCVD system. With the aid of mask patterns, researchers at TIT formed a semi-insulating (unirradiated) region in an n-type (irradiated) area using an n-type source of tetramethylsilane (TMSi). Using a p-type doping source of dimethylzinc (DMZn) together with TMSi, they also formed a semi-insulating (irradiated) region in a p-type (unirradiated) area. These results offer the potential of the laser-assisted selective growth technique for the fabrication of electronic and optoelectronic devices involving semi-insulating regions on a single GaAs wafer.

Optoelectronic Joint Research Laboratory has been conducting experiments on the selective embedded growth of $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ($x \approx 0.35$) in patterned grooves on GaAs substrates in a low pressure MOCVD system (~ 10 Torr). They found that epitaxial $\text{Al}_x\text{Ga}_{1-x}\text{As}$ layers were embedded only in chemically etched grooves and that no polycrystalline deposition occurred on SiN_x masked areas. The grooves ranged from 5 to $1000\text{ }\mu\text{m}$ width oriented along the [110] direction. The grown layers were flat and had smooth surfaces in level with the substrate surface.

- GaAs on Si

Oki Electric Industry Company, Ltd., reported the first successful fabrication of GaAs power FETs on GaAs epitaxial grown layers on a Si substrate by MOCVD and MBE. The transconductance (g_m) of these power FETs was typically 110 mS/mm which was comparable to that of FETs fabricated on a GaAs substrate. At 1 GHz, a power FET with $1\text{ }\mu\text{m}$ gate length and 5.4 mm gate width exhibited a linear gain of 10.2 dB, the saturation output power of 2.3 W and the maximum power added efficiency of 38%. These RF

performances are somewhat lower than those measured on FETs fabricated on the GaAs substrate. However, because of the high thermal conductivity of the Si substrate compared with the GaAs substrate (\sim three times larger) these power FETs showed a low thermal resistance value of $5.3^{\circ}\text{C}/\text{W}$, which was about half the value of FETs on the GaAs substrate. For heat dissipation of GaAs power devices, the FET on GaAs/Si structure appears to have an advantage over the FET on GaAs.

An n^+ -Si (100) substrate was first heat-treated at 900°C for several minutes in a H_2 and AsH_3 flow for surface cleaning in a low pressure MOCVD system. Following the surface cleaning, the two-step growth procedure was used to grow GaAs layers. The procedure involves cooling of the substrate to below 450°C and deposition of a thin, ~ 200 Å GaAs as a first layer. Then the substrate temperature was brought to the conventional growth temperature of 700 – 750°C and a vanadium-doped semi-insulating GaAs layer of 1.5 μm was grown to isolate the active layer from the Si substrate. After the deposition of the V-doped GaAs layer, growth of an undoped buffer layer of 1.2 μm , a Si doped, n -active layer of 0.2 μm , and a 400 Å n^+ -contact layer was carried out at 580°C in an MBE system.

In the FET fabrication, the gate region was recessed by chemical etching and Ti/Pt/Au was evaporated to form the Schottsky gate. The gates formed have the gate length of 1.0 μm and the gate width of 0.9 – 5.4 mm. For device isolation, selective O^+ ion double implantation was employed. A dose of $2 \times 10^{12} \text{ cm}^{-2}$ at 30 keV and a dose of $3 \times 10^{12} \text{ cm}^{-2}$ at 80 keV were used for double implantation. Evaporated AuGe/Ni/Au was alloyed for ohmic contact formation.

Researchers at Oki believe that the RF performances of power FETs can be further improved by reduction of the parasitic capacitances between the Si substrates and bonding pads.

Oki Electric has strong research interest in the monolithic integration of GaAs and Si under the future electron device project sponsored by MITI.

The Nagoya Institute of Technology, the Umeno Laboratory in collaboration with a group at Nagoya University is involved in a strong MOCVD growth program. Their growth program includes the MOCVD growth of AlGaAs and GaAs on GaAs, Si or Ge substrates, and of GaP on Si substrates leading to the fabrication of solar cells, LEDs, LDs and optoelectronic ICs.

Their scheme for the GaAs growth on Si is to insert interlayers of materials such as AlP, GaP, AlGaP, or GaAsP whose lattice constants closely match with the lattice constants of $\text{Si} \rightarrow \text{AlP} \rightarrow \text{AlGaP} \rightarrow \text{GaP/GaAsP SL} \rightarrow \text{GaAsP/GaAs SL} \rightarrow \text{GaAs}$. The idea is to relax the lattice mismatch by a strained superlattice.

Recently they have demonstrated a room temperature pulsed operation of an AlGaAs/GaAs DH laser fabricated on a p-type Si substrate using intermediate layers of GaP/(GaP/GaAsP) superlattices and GaAsP/GaAs superlattices. The diode having a stripe width of 10 μm lased at 8770 Å with a threshold current density of 8 – 10 kA/cm^2 at 23°C .

Though the threshold current density is higher than that from the usual DH lasers on GaAs substrates, because of the high thermal conductivity of Si substrates used, the diode provided a stable room operation in a junction-up configuration.

- HEMT on the Market

Sony Corporation has begun marketing a heterojunction FET called HIFET (heterointerface field effect transistor) fabricated by the MOCVD technique. The transistor is Sony's synonym for a well-known HEMT. Following the lead of Gould, Inc., which announced the commercialization of HEMTs in November 1985, Sony has now become the second commercial supplier of HEMTs in the world.

Sony's HIFET products are available in two models: the 2SK-676 with a gate width of 200 μm and the 2SK-677 with a gate width of 300 μm . Both types have a gate length of 0.5 μm . At 12 GHz, for example, the devices have noise figures of 1.2 dB and a typical gain of 11.0 dB at 300 K. Detailed characteristics of the two models are described in the *Scientific Bulletin*, 11, (1) 74, (1986).

- MOCVD-Grown Lasers and LEDs on the Market

MOCVD technology in Japan has now matured to the point where light-emitting diodes and laser diodes can be produced commercially. Toshiba Corporation is mass producing GaAs/AlGaAs LEDs with an output of 150 μW at .89 μm for short distance optical-fiber communications. Both Sony and Mitsubishi Electric have begun production of visible lasers using MOCVD. Sony's laser has a tapered-stripe cavity with an output of 5 mW at .78 μm and Mitsubishi has grown a laser with a transverse-junction stripe cavity with an output power of 5 mW at .89 μm . MOCVD has now become a very promising technology for production of large-scale laser wafers.

For a detailed description of Sony's production-type laser, refer to the *Scientific Bulletin*, 11, (1) 74, (1986).

SUMMARY

In this report, current research activities and accomplishments in MOCVD growth of several prominent institutions have been reviewed. In Japan, as in Western countries, research on and applications of MOCVD technology is being extensively pursued. The Japanese consider MOCVD technology one of the most productive and controllable methods available. They have produced many, noble GaAs-based devices by MOCVD such as LEDs, lasers HEMTs and HETs.

Several companies in Japan have started making LEDs and lasers grown by MOCVD. In the area of microwave devices, though they have demonstrated the state-of-the-art GaAs MESFETs grown by MOCVD, they have not yet adopted MOCVD for mass production. From the point of view of cost considerations and because of the simplicity of processing and fabrication, direct substrate implantation is still favored in industrial laboratories in Japan. Their work has certainly solidified the belief that MOCVD has now become a controllable, reliable and productive technology.

ACKNOWLEDGEMENTS

I would like to express my thanks to the following individuals who discussed their work and provided the information and numerous materials which are presented in this report:

Professor H. Kukimoto	Tokyo Institute of Technology at Nagatsuda
Professor T. Ikoma	University of Tokyo, Institute of Industrial Science
Professor M. Umeno	Nagoya Institute of Technology
Dr. T. Nakanishi	Toshiba Research and Development Center
Dr. N. Watanabe	The Sony Research Center
Dr. K. Kaminishi	Oki Electric Industry Company, Ltd.

APPENDIX I

KEY PLAYERS IN MOCVD GROWTH OF III-V COMPOUND SEMICONDUCTORS IN JAPAN

INSTITUTIONS	PROFESSORS	MATERIAL SYSTEMS
Nagoya Institute of Technology, Department of Electrical and Computer Engineering	M. Umeno K. Yamamoto	GaAs, GaAsP/Si plasma CVD of InP
Nagoya University, Department of Electronics	I. Akasaki N. Sawaki	GaN, AlGaN/sapphire ZnS, Se/GaP, GaAs
Tohoku University, Department of Electric Engineering	T. Hariu	
Tohoku University, Research Institute of Electrical Communication	N. Mikoshiba K. Tubouchi J. Nishizawa	AlN GaAs (MO-MBE)
Hokkaido University, Department of Electrical Engineering	H. Hasegawa H. Ohno	GaAs GaInAs AlGaAs
University of Tokyo, Institute of Industrial Science	M. Suzuki T. Ikoma	AlGaAs
Tokyo Institute of Technology at Nagatsuda, Imaging Science and Engineering Laboratory	H. Kukimoto	Ternary and quaternary alloy
Tokyo Institute of Technology at Ookayama, Physical Electronics	Y. Suematsu K. Furuya K. Takahashi M. Konagai	GaInAsP GaAs GaAlAs ZnSe (MO-MBE)

RESEARCH PROGRAMS IN THE JAPANESE METEOROLOGICAL RESEARCH INSTITUTE

Wayne V. Burt

PROLOGUE

In 1961, the Japanese Cabinet decided to look into the possibility of moving governmental units that did not necessarily need to be located in Tokyo to some location outside of the city. The purpose of the proposed move was to help mitigate the problem of the excessive population concentration in Tokyo. The end result was the creation of Tsukuba Science City located about 60 km northeast of Tokyo and about an hour's train ride from Tokyo. The area for development was selected because it was close to Tokyo and the land there was not well suited for agriculture because of relatively poor soil and a lack of sufficient water for irrigation.

In 1972, the Cabinet had selected 43 research and educational institutions that would be moved to Tsukuba Science City or were to be created there. By 1980, all 43 institutions, including two universities were situated in the new city. There are about 8000 scientists working in the city. They constitute about three-quarters of all the scientists (outside of those in the universities) that are employed by the Japanese government in the whole country.

One of the 43 was the Meteorological Research Institute (MRI), the main research arm of the Japanese Meteorological Agency (JMA). When I last visited the MRI, it was housed in dreary one-story wartime, wooden barrackslike buildings on the outskirts of Tokyo. Now it is housed in a large, gleaming white six-story brick building and fourteen smaller special purpose buildings in the new Tsukuba Science City. Many open spaces have been left in the city with wooded areas, lakes and small farms interspersed between the various institutions.

INTRODUCTION

Japan is often struck by severe natural disasters. The predominance of mountains and the surrounding seas expose Japan to severe weather conditions, frequent earthquakes, and volcanic eruptions. The Japanese Meteorological Research Institute is engaged in the study of and the prediction of meteorological, geophysical, and oceanographic phenomena and the development of technology related to the study of these phenomena. Its primary aims are protection from or mitigation of natural disasters and the prevention of environmental degradation due to the activities of man.

In the absence of the director of the Institute, Dr. K. Yanagihara, I first met with the vice-director, Dr. Y. Kono. My host for the rest of my stay was Dr. H. Iida, a physical oceanographer, and chief of the Oceanographical Research Division.

The institute has a little less than 200 employees, three-quarters of whom are researchers. About a third of the research workers have their doctoral degrees. The institute is divided into nine research divisions. Each division is divided into from two to four specialized laboratories. This article will be primarily devoted to the activities in the Oceanographical Research Division and the Marine Chemistry Laboratory in the Geochemistry Research Division with a few comments about the activities in the other divisions.

- Forecast Research Division

This is the largest and most important division. The main emphasis is on the development of improved weather forecasting techniques on all time and space scales from worldwide climatic changes down to short range forecasts of mesoscale phenomena such as heavy localized rainfalls and snowfalls, tornadoes, sea and land breezes, and fog. Orographic (terrain) effects are of particular importance in Japan because of the preponderance of mountains. A particularly startling example of the magnitude of orographic effects is shown in Figure 1. A ship steamed to the north, close into shore from the southwestern tip of Hokkaido Island for eight hours (about 150 km), constantly recording the wind speed. Each time it passed a mountain on land to the east of its path, the wind velocity dropped to a minimum of about 3 m/s (7 miles/hour). This occurred between 1400 and 1600, 1800 and 1900, and between 2020 and 2135. Each time the ship passed a valley between the mountains, the wind which was from the east, jumped up to maximums of over 15 m/s (34 miles/hour). Wind speed forecasts for small craft based on large-scale synoptic pressure charts would be of little use under circumstances such as those shown in Figure 1. Intense localized rainfall and runoff studies show the same order of magnitude in horizontal variability in those parameters.

- Typhoon Research Division

On an average, about four typhoons strike the Japanese islands during the typhoon season in late summer and early fall. They cause a huge amount of damage and loss of human life. Buildings, equipment, crops and loss of other property are caused by high winds, very heavy rainfall, storm surges and high waves. The mechanisms of each of these destructive phenomena are under study. The genesis, development, and structure of tropical disturbances are under study as part of an effort to develop numerical forecasting models for the tropics and the predictions of typhoons.

- Physical Meteorology Research Division

This division is engaged in research on the mechanisms of precipitation and the atmospheric boundary layer. Very heavy rainfall causes considerable damage in Japan. It is hoped that the forecasting of heavy rainfall can be improved and that eventually something can be done in part to control it. The studies of the boundary layer are important, both for understanding the large-scale dynamics of the atmosphere and for a number of applications in such studies as mesoscale meteorology, evaporation, urban climatology, aeronautical meteorology, and air pollution dispersion.

- Applied Meteorology Research Division

The main subjects under study are: fundamental studies on atmospheric diffusion and behavior of air pollutants, studies on the relation between human health and air pollutants and pollen, studies on the correlation of air pollution and atmospheric conditions and studies on local climate modification which is influenced by the development of cities, construction of industrial zones and man-created thermal energy.

- Meteorological Satellite Research Division

Japan has its own stationary meteorological satellite located over the equator at the approximate longitude of Tokyo. This division is working on the development and improvement of meteorological satellite observation instrumentation and the improvement

of remote sensing algorithms. Research is also carried out on weather radar, laser radar and acoustic radar, using a 213-m-high meteorological tower for field tests of new instruments.

- Seismology and Vulcanology Research Division

The Japanese islands are subject to frequent earthquakes, and Japan has approximately 70 active volcanoes. The Japanese Meteorological Agency is responsible for issuing tsunami warnings and information on earthquakes and volcanic eruptions. The emphasis of this division is on developing and improving methods and instrumentation for earthquake and volcanic eruption prediction.

- Upper Atmosphere Physics Research Division

This division studies the upper atmospheric radiation budget and the atmospheric constituents that have important influence on these budgets including stratospheric ozone, carbon dioxide, water vapor, aerosols and clouds. These constituents absorb scatter and reflect solar radiation. Nitrogen oxides and chlorine oxides are studied because of their effect on atmospheric ozone. Cosmic ray intensity and solar activity are also under study.

- Geochemistry Research Division

Dr. Yukio Sugimura, head of the Marine Chemistry Laboratory of the Geochemistry Research Division commutes from Tokyo. He met me at my hotel and conducted me via taxi, subway, and train to the institute. His laboratory is one of the largest at the institute in terms of personnel and space. The Japanese government has recently become acutely aware of the potential deleterious effects of man's activities on the worldwide environment. Dr. Sugimura told me that he had all the funds that he could use both for personnel and equipment. He showed me about a dozen large laboratory rooms with all the newest instruments for carrying out chemical analysis on air, water and earth samples.

To watch and forecast the features of the earth's changing environments are important aims of the Japanese Meteorological Agency. This division plays a role in defining the chemical environment of the earth: the atmosphere, hydrosphere and lithosphere through the study of time and space variations in the concentrations of chemical substances.

Recently, as a result of increasing human activities and consequent introduction of anthropogenic materials, the chemical environment of the earth has rapidly changed. The studies in the laboratory are focused on obtaining information on the following subjects: the consequences of increasing CO₂ in the atmosphere, the exchange rate of chemical substances between the ocean and the atmosphere, the behavior of natural and artificial chemicals in the air and ocean, and the diffusion rate of chemical substances near the ocean floor.

Various chemicals both natural and artificial are used as tracers to study circulation and both vertical and horizontal diffusion in the ocean and the atmosphere. These include CO₂ and its isotopic composition, radioactive materials from nuclear explosions, trace metals, and krypton 85 from nuclear fuel processing plants in France and England.

- Oceanographical Research Division

Since Japan is surrounded by the sea with no cities that are more than 140 km (86 miles) from salt water, there is a great demand for research on the marine environment. Some of JMA's objectives are to predict unusual ocean surface phenomena and to prevent maritime accidents and marine pollution. It operates six research vessels ranging in length from 42 m to 82 m and with berthing capacities ranging from 38 to 78. In addition, it regularly operates 56 tidal stations and four meteorological-oceanographic monster buoys.

Japan has its own "Bermuda Triangle." A number of large cargo ships have been lost at sea in the area of the Kuroshio Current south of the main Honshu Island. For example, five big ships were lost during the winter of 1980-1981. A great deal of effort is going into two studies. In one, the institute is trying to find out why this happens, and in the second, the objective is to develop a warning system that will be able to predict up to seven days in advance the unusual conditions at the sea surface that may cause large vessels to sink. There is some consensus that occasional colossal single waves or short trains of waves may be responsible.

The institute has built a large, 6-m by 6-m experimental wave tank with a sinusoidal wave generator on the side and a wave sink on the other end. There is a wind tunnel over the whole tank. The tunnel is on tracks so that it can be rotated from 0 to 60° from the direction in which the waves are moving. This facility was especially designed for studying the effect of the wind on swells propagating in different directions than the wind direction. The researchers believe that large freak waves may occur when strong winds shift directions after a high sea has been set up.

In the second study, the researchers are going back in time and hindcasting the sea and swell conditions at the time and in the areas where ships have been lost during the winter monsoons. This is being done with historical weather maps by well-established and proven methods. If the sea and swell conditions that occurred when the ships were lost had frequently occurred in the past when no ships were lost, then the ships that were lost may have had errors in their design, or been operated incorrectly, or been lost due to some other cause than the sea and swell conditions. If they find that the sea and swell conditions occurring when ships were lost have something in common that is unusual or different from normal or average conditions, then they would like to develop a method for forecasting these unusual conditions that may have contributed to the losses.

One special buoy is anchored in the center of the "Bermuda Triangle" where most of the ships were lost. In addition to gathering other oceanographic and meteorological data, it has sensors for recording sea and swell conditions and sends the data back to the institute in real time via a satellite link.

In another study, JMA makes a temperature-salinity section along 130° E longitude from Japan to 12.5° N latitude, the latitude of Guam. They also maintain some current meter moorings along this line. There is some evidence that these data may show the first signs of the formation of an El Niño event.

Modelers of ocean circulation in the institute have a supercomputer dedicated to their use. Their models range in scale from large-scale coarse grid ones to very fine grid ones to model the effect of mesoscale meteorological events on the circulation.

Other studies underway or recently completed include: the variability and mechanisms of variability of the Kuroshio Current system, the application of satellite data to oceanography, the directional characteristics of wind waves, the characteristics of

microwave backscattered from the sea surface, the investigation of observations of oceanic phenomena using the microwave radiometer, the counter current under the Kuroshio Current, and orographic effects of land terrain on near shore winds.

SUMMARY

The idea behind the development of Tsukuba Science City appears to be working out very well. The air above it is sparkling clear when compared to the smog that envelopes Tokyo much of the time. Except for a few diehards that commute from Tokyo, most of the workers at the Meteorological Research Institute live nearby or further out in the country. The institute has two large parking lots for bicycles, something that would be unheard of in Tokyo.

I was impressed by the down-to-earth practicality of most of the various research projects that were discussed and even more impressed by the wide variety of specialized facilities and equipment and space that is available to the research workers. In a full day of interviewing, I did not hear any grouching about lack of funds or facilities. The closest thing to grouching that I heard was from the head of one of the major divisions who was retiring soon at the mandatory age of 60 and was preparing for his second career as a science teacher in a junior high school.

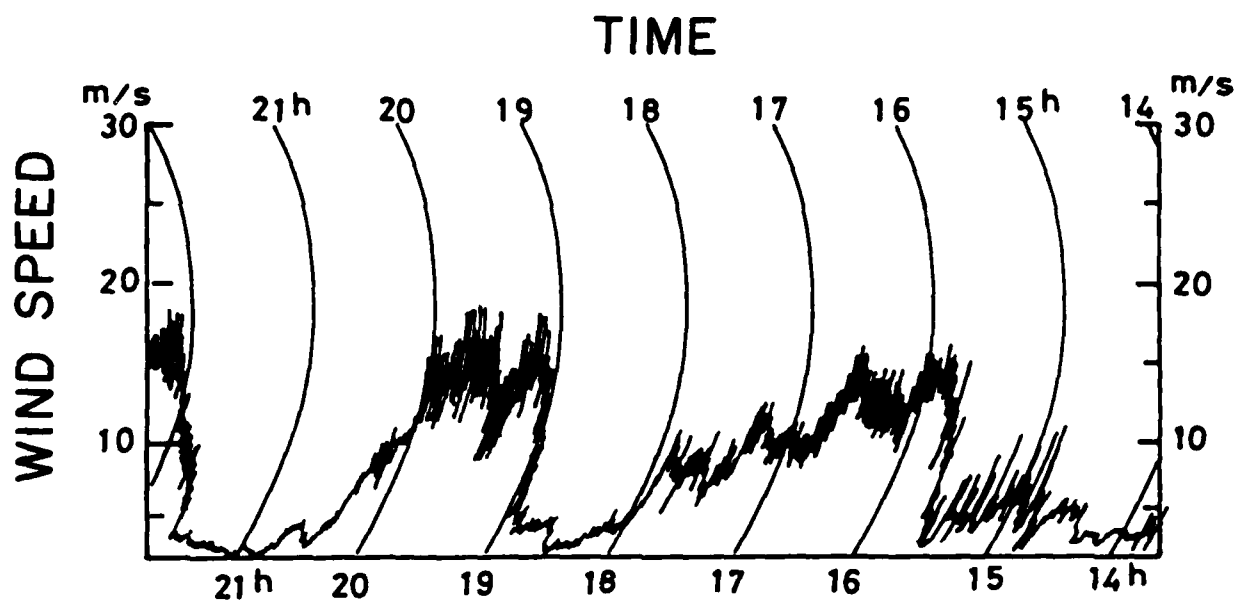


Figure 1. The wind speed that was measured on a ship sailing up the east coast of Hokkaido Island.

THE OCEAN RESEARCH INSTITUTE;
UNIVERSITY OF TOKYO

Wayne V. Burt

INTRODUCTION

The Ocean Research Institute of the University of Tokyo was founded in 1962 by an act of the Japanese Diet, the national legislative body. The institute is Japan's national center for all types of marine research. It serves as a coordination center for participation of scientists from all over Japan in projects supported by the Ministry of Education, Science and Culture.

The institute has acted as a national representative in many international cooperative research projects. These include:

- the Geodynamics Project (GDP) 1973-1977,
- the Global Atmospheric Research Program (GARP) 1973-1975,
- the International Phase of Ocean Drilling Program (IDOP) 1975-1984,
- the Monsoon Experiment (MONEX) 1983-84,
- the Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS) 1984-1985,
- KAIKO, a Japan-France cooperative research program on the Japanese Trench, 1984-1985, and
- the Ocean Drilling Program (ODP) 1984-.

The institute welcomes the opportunity to carry out joint research efforts with both individual scientists and institutions in Japan and abroad.

The current director of the institute is Professor Akihiko Hattori, head of the Division of Marine Biochemistry. The two deputy directors are Professor Tomio Asai, head of the Division of Marine Meteorology, and Professor Takahisa Nemoto, head of the Division of Marine Planktology.

Since 1972, the institute has grown into the largest, most comprehensive oceanographic laboratory in Japan with a staff of over two hundred. About a third of the staff are research scientists. Many visiting researchers, including scientists and students from other Japanese institutions and foreign countries are involved, each year, in the various research and instructional programs at the institute for a total of over eight thousand man-days.

Research in all of the basic disciplines of marine science is done in one or more of the 15 research divisions of the institute. An outline of some of the research activities in each division will be included in this report. The usual composition of each of the divisions consists of a full professor, an associate professor, two research associates, two technicians, and some graduate students.

An average of 80 graduate students are carrying out thesis and other research projects at the institute. Graduate students from the University of Tokyo take their degrees in departments in the Schools of Science and Agriculture while carrying out their thesis research at the institute. It is interesting that a quarter of the students are from foreign countries, including the United States, England, Brazil, India and many of the

nearby countries in eastern Asia.

- Facilities

The institute is housed in its own modern campus in the Nakano-ku district of Tokyo, about 9 km (5 miles) west of the main campus of the University of Tokyo. The two main buildings and several small service buildings have a combined floor space of 14,175 m² (153,500 ft²). Up-to-date electronic equipment is available in special laboratories for:

radioisotope studies,
computing,
electron microscope studies,
x-ray analysis,
mass spectrophotometer studies,
ultracentrifuge work,
biological productivity studies,
cultivation of microalgae and bacteria,
low temperature studies, and
radioactive dating.

The institute also operates the Otsuchi Marine Research Center, a coastal marine laboratory dating back to 1979. The laboratory is in Akahama on the north shore of Otsuchi Bay on the northeastern coast of the island of Honshu, 400 km (250 miles) from Tokyo.

The center has 2914 m² (31,350 ft²) of floor space with modern laboratories and electronic equipment for research programs in physical, chemical, geological, and biological oceanography and fisheries science. It has all the amenities of a modern marine station, including housing for 20 visiting scientists, a library, an auditorium, and three small craft ranging up to 16 tons and 17.7 m (58 ft) in length.

The Ocean Research Institute operates two oceangoing research ships. The 470 ton 45 m long (157 ft) *Tansei Maru* with quarters for 11 scientists, normally operates within a radius of 1500 km (800 nm) of Tokyo. The much larger 3200 ton, 95 m long (306 ft) *Hakuho Maru* has berths for a scientific party of 32. With a cruising range of 28,000 km (15,000 nm), its cruise tracks make a spider web of the North and South Pacific Oceans that extend from the Bering Straits in the Arctic to the Ross Sea in the Antarctic and including seas of the East Indies and the eastern part of the Indian Ocean. The ship is equipped with most of the latest types of electronic oceanographic and navigational equipment. The institute staff is presently making plans to construct a new ship to replace the *Hakuho Maru*.

- Publications

The institute issues four series of publications:

- the *Bulletin of the Ocean Research Institute*, University of Tokyo, Volume numbers 1 to 21,
- the *Otsuchi Marine Research Center Reports*, Volume Numbers 1 to 10,
- the *Preliminary Reports of the Hakuho Maru Cruises*, Volume Numbers 1 to 41,

- the *Publications List of the Ocean Research Institute*, an annual listing of papers published by the staff, students and visitors at the institute. Thirteen annual lists have been published to date with two to three hundred titles in each list.

RESEARCH PROGRAMS

- Physical Oceanography

Structure of the general circulation in the world's oceans and their fluctuations.

Global features of the oceanic tides and their influence on related phenomena.

Processes and mechanisms of large-scale ocean-atmosphere interactions.

The deep circulation and internal and surface tides in the Philippine Sea using about twenty moorings at a time with current meters, bottom-mounted tide gauges and inverted echo sounders. They are also using velocity profilers and a SOFAR system to determine currents in the Philippine Sea.

- Marine Meteorology

Air mass transformation processes over the ocean and heat budget studies.

Mesoscale atmospheric disturbances associated with heavy rainfall.

Extra tropical cyclones using numerical experiments and statistical analysis.

Local wind systems in the coastal regions of Japan where orographic effects may be large, due to the rough topography of the land.

The islands of Japan are surrounded by the Pacific ocean and several seas. The islands have many bays and other indentations plus a large inland sea. In addition, the land masses have very rugged topography. These two factors have a marked effect on the variability of the weather sometimes over very short distances. For example, when I took a train from Nagoya to Tokyo last February it was clear in Nagoya when I left. About half way to Tokyo, it was snowing heavily. When I arrived in Tokyo, the sun was out again.

The Division of Marine Meteorology at the institute spends a good deal of time in the study of local variability in the weather due to the orographic effects and the surrounding seas and the ocean. One of the most interesting studies has to do with the intense variability of rainfall both in time and in space. One case study had to do with a short period of time when an extreme amount of rain fell on the city of Nagasaki. An intense frontlike rainband propagated east southeastward over northwestern Kyushu, with a speed of forty kilometers per hour. The rainband was apparently orographically trapped when it arrived over the city of Nagasaki where it stopped moving and changed from a frontlike structure to a blob structure with a diameter of about one hundred kilometers. During the five hours that the blob stayed over the city, record rainfalls as large as 412 mm (sixteen inches) were recorded. During the period of heavy rainfall over Nagasaki, a new cloud cluster over the sea west of Nagasaki moved toward the city with a speed of sixty knots. It kept developing and moving eastward and eventually merged with the rainstorm over Nagasaki.

The institute has made several studies of the movement and dissipation of air pollutants over the city of Tokyo and surrounding areas including Tokyo Bay and the Kanto Plain north of the bay. The importance of air pollution in this highly industrialized area is highlighted by the location of over one hundred air pollution monitoring stations in an area only a few miles wide surrounding Tokyo Bay. Land and sea breezes have been shown to be important factors in the distribution of air pollutants whenever the local winds due to pressure gradients fall below five m/s (ten knots). A frontlike phenomena often forms over the Kanto Plain at the time of day when the sea breeze changes to a land breeze. The front sometimes is followed by a heavy concentration of pollutants that are mainly from vehicle exhausts.

In other studies on the effects of land and sea breezes, the institute found, that in summer, the near shore water surface temperatures showed a very large diurnal variation due to land and sea breezes. The maximum temperatures occurred about midday and ranged from 0.9°C to 2.5°C above the daily minimums.

- Submarine Geophysics

Marine geodetic and marine geophysical studies based on gravity measurements that are made on almost all cruises of the R/V *Hakuho Maru*.

Measurement of geomagnetism and its geophysical interpretation in the study of the ocean floor tectonics of the Pacific Ocean.

Geodetic studies over the ocean by use of satellites with emphasis on high latitude areas.

Development of equipment and studies for improving marine geophysical research.

- Submarine Sedimentation

Marine sedimentation, especially at the margins of active plates such as trenches and arc basins. The techniques employed include the use of seismic profilers, sidescan sonar, piston coring, dredging as well as extensive on-shore sedimentological analyses.

The marine geology of the ocean floor including its morphological and physical characteristics.

Phenomena occurring at the sediment-sea water interface.

The division is also deeply involved in the multinational Ocean Drilling Program.

- Ocean Floor Geotectonics

Measurement of the remanent magnetism on piston cores and samples from the Ocean Drilling Program and the determination of geomagnetic field variations, ocean floor spreading and sedimentation rates based on magnetic stratigraphy.

Petrological and paleomagnetic studies of samples dredged and drilled from the sea floor, seamounts and ocean islands.

Studies of the evolutionary history of island arcs, based on paleomagnetic properties

of ophiolites. Studies of sea level changes on ocean islands, and the formation of a general scheme of vertical crustal movements.

- Marine Organic Chemistry

Submarine vulcanism and hydrothermal activity. Determination of the chemical composition and stable isotope ratios of various components in volcanic rocks collected from midocean ridges, oceanic islands and marginal sea floors.

The distribution and circulation of stable isotopes in the ocean.

The development of analytical techniques for the concentration and measurement of isotope ratios with emphasis on automated microanalysis of volatile elements and radioactive nuclides.

- Marine Biochemistry

The nitrogen, carbon, and phosphorus cycles and their interactions in the oceans.

Isotope fractionation and its application to the analysis of biogeochemical processes.

Biochemical and physiological studies of nitrogen and carbon metabolism.

- Physiology of Marine Organisms

The physiological and biochemical adaptations of migratory fishes such as eel, salmon, trout, mullet and flounders to hypotonic fresh water or hypertonic seawater during seaward or upstream migration.

Fish reproduction under the influence of different ionic and osmotic environments ranging from fresh to salt water.

Adaptive mechanisms of phytoplankton to various environmental factors such as light intensity, salinity, temperature, dissolved oxygen and turbidity.

- Marine Ecology

The structure of benthic communities and regional ecosystems.

Estimates of the standing crops of benthic communities.

The vertical distribution of organisms in bottom sediments and the stirring effects of organisms on the sediments.

Reproductive and larval ecology of the benthos.

- Marine Planktology

The role of plankton in the food chain and energy flow in the marine ecosystem.

The taxonomy, life history, ecology and physiology of important species of plankton.

Bloom, mass propagation of plankton and the mechanisms for the formation of red tides.

- Marine Microbiology

Microbiological and chemical studies on the processes of decomposition of organic matter in the sea.

The distribution of bacteria in the various marine environments.

The taxonomical characteristics of marine bacterial flora.

Ecological interactions between different species of bacteria and between bacteria and other marine organisms.

- Population Dynamics of Marine Organisms

The population dynamics of marine organisms and related subjects including assessment of standing stocks, management and prediction of exploited fish stocks.

Experimental laboratory studies on population dynamics, mortality of early life stages, fecundity of adults and the effects of food abundance on survival rates.

The development of a method for species identification of plankton and bacteria by pattern analysis.

The production, structure and dynamics of a coastal community.

- Biology of Fisheries Resources

The distribution, life history, settlement, feeding, environmental factors affecting reproduction and growth, composition and succession of marine sessile fauna.

Life histories of fishes of diverse habitats in terms of their adaptive strategies at various developmental stages.

- Fisheries Oceanography

Factors governing the distribution and movement of marine biological resources in the fishing grounds. These include the distribution of nutrients and food as well as physical oceanographic structures and their fluctuations such as currents, fronts, thermoclines, eddies and various mixing processes.

- Fisheries Ecology

The systematics and ecology of fishes.

The early life history of fishes.

Application of hydroacoustic techniques to estimations of fish abundance in behavior studies.

Analysis of schooling behavior of fishes.

The efficiency of fishing gear.

SUMMARY

After visiting most of the major marine science laboratories in the world, I found that in comparison with other laboratories, the Ocean Research Institute of the University of Tokyo ranks, in my opinion, as one of the first-class institutions. This is in terms of the qualifications of the staff, the laboratories, ships and scientific equipment available for their research programs and the breadth and depth of their research programs.

PCARRD, THE PHILIPPINE COUNCIL FOR AGRICULTURE
AND RESOURCES RESEARCH AND DEVELOPMENT OF THE
NATIONAL SCIENCE AND TECHNOLOGY AUTHORITY

Wayne V. Burt

The economy of the Republic of the Philippines is almost wholly dependent on agriculture and other natural resources. Beginning in 1972, it was realized that major efforts should be made to organize and direct the nation's research efforts in such a way that new technologies could be efficiently applied to increase the yield in agriculture, fisheries, and the exploitation of other natural resources. Yields had to be increased and new products developed to take the place of some costly imported materials if the country's economy was to be improved and the standard of living increased.

Now the country has a well-organized system for directing and controlling its resources research. The backbone of the system is PCARRD which has the power to continually review all research proposals in agriculture and other natural resources and to select and recommend the priorities of all research proposals to the Office of Budget and Management for funding.

PCARRD has the mandate to:

- define goals, purposes and scope of research and development necessary to support progress in crops, livestock, forestry, fisheries and mining for the nation on a continuing basis;
- formulate the national agriculture and resources research and development programs on a multidisciplinary, interagency and systems approach for the various component commodities;
- establish a system of priorities for crops, livestock, forestry, fisheries, and mining research and development, and provide meaningful mechanisms for updating these priorities;
- develop and implement a fund-raising strategy for supporting agriculture and resources and development;
- program the allocation of all government revenues earmarked for agriculture and resources research to implement a dynamic national research and development program;
- establish and support and manage the operation of a national network of centers of excellence for the various research and development programs in crops, livestock, forestry, fisheries, farm resources and systems, mineral resources and socioeconomic research related to agriculture and natural resources;
- establish a repository for research information and develop a mechanism for full communication among workers in research, extension, and national development;
- provide for a systematic research and development program in agriculture and for the upgrading of research institutions;

- provide for appropriate incentives to encourage top-notch researchers to remain working in their respective research programs in agriculture and other resources; and
- enter into agreements and other relationships with other similar institutions or organizations, both national and international, for the furtherance of the above purposes.

Annually, the staff of PCARRD makes a thorough review of all research projects that are underway and publishes a short review of the status of each project. Project results are divided into two categories, i.e., those where the technology that has been developed is ready for dissemination to the public, and those where the technology appears to be worthwhile but needs further verification.

The annual report, called *Research Highlights from the PCARRD Network* makes fascinating reading. I sat down and read the copy given to me from cover to cover. A good deal of the research is aimed at the subsistence farmer. For example, the farmer is taught how to make brick and tile with simple tools.

The coconut grows in many places in the Philippines. Two recent technologies that were disseminated were how to make lacquer from the trunks of the trees, and how to make simulated milk from the coconut milk which can be used in making ice cream, bakery goods, and confectioneries. Acceptable cheeses can be made from 50% regular milk and 50% coconut milk.

PCARRD presently uses two strategies to assure that technology reaches the end-users fast and efficiently. These are pilot programs and an outreach program.

In the pilot project strategy, a package of technology is tried on the farmer's field with a concomitant support system such as credit, market, extension and training the farmer. The main purpose is to determine whether the technology will work under the farmers' or producers' conditions and scale given the essential inputs. The outreach program uses print media as its main communication vehicle. Specific technology for a specific region is written in both the local vernacular and in English.

PCARRD has a national network for scientific literature which it stocks in 98 libraries. It also has organized a network of Regional Applied Communications Offices (RACOs) to implement more localized communication activities based on the needs of a particular region. These are also outposts of PCARRD and are used as vehicles to plow new and improved practices back to the user system.

I met several times with the charming deputy assistant director of PCARRD, Dr. Elvira O. Tan. She is in charge of development and financial management of the overall program as well as director of the Fisheries Research Department. My host for much of my stay in the Philippines was Dr. Tan's assistant, Ramy Pelayo, who recently received his master's degree in Marine Resources Management from Oregon State University. I was very much impressed by Dr. Tan's knowledge, dedication and drive in a country where it is unusual for women to attain high managerial positions in government agencies.

OPTOELECTRONICS IN THE PEOPLE'S REPUBLIC OF CHINA

James L. Merz

INTRODUCTION

During the three-week period between 3-24 October 1985, I visited many of the major laboratories involved in research and development of compound semiconductors in the People's Republic of China.

- Beijing Institute of Semiconductors
- Changchun Institute of Physics
- Shanghai Institute of Metallurgy
- Shanghai Institute of Technical Physics
- Shanghai Jiaotong University

The overall impression formed during this visit was a very positive one: the Chinese are building up a capability for research in important aspects of compound semiconductor materials and devices, such as MBE, reactive ion etching, HEMT, multiquantum well lasers, etc. Their technical people are extremely intelligent and industrious; although their country is painfully underdeveloped, they recognize the disastrous consequences of the cultural revolution, and, with windows and doors open to the West, they are working very hard to catch up in these technologies. They are also identifying markets where they might have some impact. In the last five years they have sent many visiting scholars and researchers to the United States, Europe, and Japan; although these people have not always been employed most efficiently upon their return, many of them now have key positions in which to develop the technology they learned abroad, and are effectively doing so. The earlier emphasis on heavy industry is changing, and the most recent "Five Year Plan" includes a strong concentration in the high tech area. (The 1986-1991 Five-Year Plan includes three high tech areas: electronics, computer applications, and materials.) In this report I will try to assess the compound semiconductor technology that I observed in China, comment on related technologies, and make a few suggestions concerning our future interactions with the Chinese.

THE THIRD CHINESE CONFERENCE ON INTEGRATED OPTICS (CCIO'85)

This conference was held at the Shanghai Jiaotong University, 15-20 October, and was the primary reason for my trip to China. Approximately 100 participants attended from laboratories throughout China, four of whom traveled with us for 40 hours by train from Changchun to Shanghai, ample time to sample their conference contributions! Three scientists from the United States, including myself, were invited to give review talks:

- "The Crossing Channel Electrooptical Modulator and its Comparison with Other Modulators," by William S. C. Chang, University of California, San Diego,
- "Integrated Optoelectronic Devices for Integrated Circuits and Communications," James L. Merz, University of California, Santa Barbara, and
- "Research Advances in Lightwave Communication Systems," by Tingye Li, AT&T Bell Laboratories, Crawford Hill, New Jersey.

A fourth invited American speaker, James H. Cole of the Naval Research Laboratory, was denied approval to attend the conference at the last minute, causing considerable consternation among our Chinese hosts. I was therefore the only speaker on the entire program to present a talk in English.

Four other invited talks were given by Chinese participants on the following subjects:

- "A Prospect for Integrated Optics," by Professor Chen Yi-Xin, who was the conference organizer, from the Shanghai Jiaotong University,
- "Materials for Integrated Optics,"
- "Application of Bistability in Optical Computers," and
- "Integrated Optics and Microfabrication."

The contributed papers were approximately evenly distributed between compound semiconductors and electrooptic materials such as LiNbO_3 . In both cases, there was emphasis on the more theoretical or computational aspects of device design and evaluation compared to actual device fabrication. This emphasis was observed stronger than is usual at international conferences on integrated/guided wave optics, and reflects the current situation in Chinese laboratories. For example, there were two entire sessions on the analysis and measurement of dielectric waveguide characteristics with papers describing complex calculations for rectangular guides, dispersion analysis, etc. Many of the measurement papers described techniques that have been in use in Western laboratories for a number of years, such as loss measurements utilizing multiple prisms. However, some reasonably good results were reported for the fabrication and evaluation of semiconductor lasers, detectors, and other circuit components. For example, a low threshold (34 mA) 1.3- μm -ridged waveguide double heterostructure (DH) laser was reported, and a constricted DH AlGaAs laser made by LPE was described. The state of this technology will be described in more detail below since visits to the major semiconductor laboratories made possible a detailed discussion of recent results.

For purposes of calibration of the quantity and quality of the Chinese activity in optical communications, a very interesting talk was given at the conclusion of the conference by Professor Chang, an eminent faculty member of the Shanghai Jiaotong University, who had just returned from the International Conference on Integrated Optics and Optical Communications (IOOC) held in Venice, Italy. Professor Chang summarized the major advances reported at IOOC, and made a number of comments to his colleagues concerning the Chinese participation at this conference. Of 209 papers presented at the IOOC, only three were given by mainland Chinese authors, plus another that was collaborative with Professor Chen Tsai, University of California, Irvine. One paper was given by a student from Jilin University on coupled cavity lasers. Professor Chang exhorted his colleagues to participate in such conferences in greater numbers in order to gain direction for future research, to change the research emphasis from theoretical to applications-oriented experimental work, to work harder on the mastery of English, and to improve the quality of Chinese research.

EPITAXIAL LAYER GROWTH

- Liquid Phase Epitaxy (LPE)

China is LPE country--every laboratory I visited had several LPE systems, and some labs had many (e.g., Shanghai Institute of Metallurgy had at least ten). These systems are used primarily for GaAs, although some work is underway on InP-based materials. They are well-designed, and yield good material suitable for optical device application. They typically have five or six wells accommodating 10×12 substrates, and use a horizontal configuration with manual slider and movable furnace. To date, essentially all device results reported by the Chinese at domestic and international meetings utilize LPE material.

- Molecular Beam Epitaxy (MBE)

There are currently four MBE machines in the People's Republic of China, and I saw three of them. They are located in the

- Beijing Institute of Physics,
- Beijing Institute of Semiconductors,
- Changchun Institute of Physics, and
- Shanghai Institute of Metallurgy.

They are all designed and manufactured in a factory in Shenyang, Liaoning Province, in the northeastern part of China. Frankly, none of them work too well at present but the Chinese are determined to change that. The design uses sources that point upwards (the substrate points down), and six sources can be used; typically these are Ga, Al, Si, Be, and two As sources, each with a manual shutter. The vacuum system is quite good and can typically reach 2×10^{-10} Torr. Analysis equipment included is HEED, Auger electron spectroscopy, and mass spectroscopy.

I understand the best results were obtained at the Beijing Institute for Semiconductors, e.g.,

bulk GaAs mobility at 60 K	80,000 cm ² /V.s
2DEG GaAs mobility at 4.2 K	320,000 cm ² /V.s

The existence of the two-dimensional electron gas (2DEG) was confirmed by the observation of Shubnikov-deHaas oscillations, but the low-temperature mobility is nearly an order of magnitude below the current state-of-the-art. (The bulk result is reasonably good.) Furthermore, even these mobilities are not reproducible between runs, and background contamination is currently a problem. For example, the radiative efficiency of material from these machines is presently too low to make double-heterostructure lasers, and for some MBE samples, no photoluminescence is observable. (This is reminiscent of John Arthur's earliest MBE attempts at Bell Laboratories in 1967-68 when his GaP layers showed no luminescence!)

- Metalorganic Chemical Vapor Deposition (MOCVD)

(The above paragraph accurately summarizes the current state-of-the-art of MOCVD in China--zero! However, they have every intention of doing something about that.)

. A Comment on Equipment

The Chinese would like to purchase commercial high tech equipment such as MBE and MOCVD reactors from Japan and the Western suppliers. As will be described below, they

have done this to a surprising extent. However, they are limited in their ability to do so by two factors:

- They do not have sufficient foreign currency to be able to buy as much equipment as they would like, and, more importantly:
- Many high tech items are included on the list of equipment that Japan and the Western countries have agreed to *exclude* from export to China and the Soviet Union. (This is monitored through a Paris-based Coordinating Committee, COCOM.) The list includes (or included) MBE, commercial MOCVD, electron-beam exposure systems, high speed electronics such as 500 MHz oscilloscopes, streak cameras, and other sophisticated electronics equipment, as well as materials and equipment for nuclear and space development. (Note: During my visit in October I was told that this equipment was included on the list. I have subsequently learned that COCOM removed certain items from that list in October, and I am not sure if the Chinese were referring to the original or revised list. Furthermore, a story appearing in the *Japan Times* on December 18 stated that the United States is planning to streamline the licensing procedures, in order to "speed approval of nonstrategic high technology exports to Beijing--now consisting of 75% of growing U.S.-China exports." Thus, such items as personal computers, semiconductors, fiber optics, and electronic instruments will not have to be cleared by COCOM. No list of "nonstrategic electronic instruments" was given. It appears, therefore, that although the Chinese would like to import more equipment than we will currently allow, the situation is indeed easing for them.)

RESEARCH ACTIVITIES AT INSTITUTIONS VISITED

- Beijing Institute of Semiconductors

Chinese Academy of Sciences
Beijing, People's Republic of China
Institute Director: Professor Wang Chiming

. Overview

The institute was established in 1960 as an independent institute, separate from the Shanghai Institute of Physics, with which it was earlier joined. It consists of 11 different divisions, including semiconductor materials, new technologies, surface, microwave, and optoelectronic devices, chemical analysis, LSI, CAD, and semiconductor physics. The total staff exceeds 1000 people, with more than 500 researchers and five full professors. As with all of the institutes of the Chinese Academy of Sciences (Academia Sinica), students can obtain graduate degrees through the institute under the direction of full-time institute faculty. The most famous of these faculty members is Professor Huang (of Born and Huang fame). It is interesting to note that approximately 100 researchers are currently abroad studying as visiting scholars; this is a significant fraction (about 20%) of the total research staff, and suggests the importance they attach to their visiting scholar program.

I was unable to visit many of these divisions, and concentrated on compound semiconductors. Their MBE machine was in the Division of Semiconductor Physics, and will be used to study GaAs/AlGaAs superlattices and the physics of 2DEG, as well as make quantum well devices. The semiconductor physicists are also interested in band structure of a variety of materials, electron spectroscopy, and amorphous Si, including nipi

structures, which they are making with CVD.

A new laboratory building is currently under construction, which will add approximately 25,000 m² to their facility. Completion date is expected to be in late 1986 (although it is my impression that construction goes very slowly in China). They currently have a 13 μ m photolithography capability.

I did not visit the Shanghai Institute of Physics, which has another of the Shenyang MBE machines. The two institutes have established a joint program to investigate surface physics using the two machines.

. Bulk Crystal Growth

They are doing LEC growth of both GaAs and InP with two homebuilt pulling machines. They grow two-inch GaAs semi-insulating (Si) material, and one-inch InP. They claim low dislocation densities in this material. (For example, for InP, they get etch pit densities less than 1000 cm⁻² by alloying with Ga or Sb. Their GaAs results are similar with In added.)

. Optical Devices

The first semiconductor laser made in China was a diffused homojunction device made in 1963. Semiconductor laser R&D continues in the Division of Optoelectronics of Semiconductors. Their GaAs/AlGaAs DH lasers utilize proton bombardment, an obsolescent technology into which they presently find themselves locked because of the requirements of a station-to-station system in use since 1979. Nevertheless, these lasers are reasonably good for proton bombardment technology because of very uniform LPE layer growth; they have threshold currents of 40 mA and differential quantum efficiencies of 70%. I also think it impressive that they have had an optical communication system for six years, and that some cities in China have long wavelength (i.e., InP-based) optical communication systems.

They have an extensive effort focused on InP/InGaAsP lasers for use at 1.3 μ m made by LPE. They are trying to improve the quality of the epitaxial layers, as evidenced by the threshold current density and device lifetime of broad area lasers. They are also developing a variety of stripe geometry lasers, such as ridge waveguide lasers, double-channel planar buried heterostructure lasers, and mass transport lasers. The latter, made by annealing mesa-etched devices at a temperature at which InP material is transported to the mesa edges embedding the active region with lower index material, are the most impressive, and are competitive with similar laser structures fabricated in the West: threshold current of 18 mA with extremely linear light current curves.

Work on visible lasers is also underway, but they are way behind the U.S. and Japan in this area. They are just starting to work on available photodiodes (APDs). Their future laser research plans include quantum well lasers made with their MBE machine, and the development of InP/quaternary lasers using an MOCVD system that they hope to import if the COCOM licensing problems can be solved.

. Electronic Devices

As described above, their electronic device program utilizing MBE is just now starting. Although they have observed 2DEG, their material quality is generally poor and

nonreproducible. When they have the epilayer growth under better control, they also plan to work on heterojunction bipolar transistors (HBT). It should be noted that one of the researchers in the Beijing MBE group was taught this technology by Professor H. Sakaki at the University of Tokyo.

. New Technology

Another division of the institute is called "New Technology," with plans for research in such areas as ion implantation, x-ray and electron beam lithography, and dry etching techniques. I had the distinct impression, however, that most of this work will be future activity, rather than current. For example, they expect to obtain a 600 keV ion implanter in the near future, and plan to work on reactive ion etching of both Si and GaAs.

The institute's photoluminescence capability is quite good, with a mode locked argon ion laser driving a dye laser with 10 ps pulses. Research with this system is directed at very current problems such as quantum well luminescence and interface luminescence (such as that recently published by my laboratory) from home-grown MBE samples.

- Changchun Institute of Physics

Chinese Academy of Sciences

Changchun, People's Republic of China

Institute Director: Yu Jiaqi

Honorary Director and Distinguished Scientist: Xu Xurong

. Overview

This institute is half the size of the Beijing Institute for Semiconductors, with about 500 employees, 200 of whom are M.S. or Ph.D. equivalents. (Note that they use the word "equivalents;" in the past China has not had a degree system comparable to ours so "experience" was used instead. Of course, they now offer graduate degrees that they feel are comparable.) Again, there is a heavy emphasis on training abroad--Changchun currently has about 40 graduate students abroad which again represents about 20% of their researchers.

The emphasis in this institute is on solid state luminescence for displays, indicator lamps, and other solid state sources. For example, there is a great deal of work on thin film and powder displays utilizing wide band gap II-VI compounds such as ZnS and ZnSe. I was shown a dc panel display with yellow emission, based on the ZnS/ZnSe: Mn system which was as bright as any produced elsewhere in the world. (This is a technology that the Japanese currently dominate.) They have also made the largest flat panel ac electroluminescent display yet reported, 2.5 x 3.0 m².

As far as compound semiconductors are concerned, the emphasis is on fundamental knowledge particularly of fast electronic processes in these materials. Professor Xu is internationally known in this area, and works on such problems as the generation and detection of ps and ns pulses, fast spectroscopy, and semiconductor processes involving very fast phenomena (e.g., energy transfer). The next International Conference on Luminescence will be held in Beijing in the summer of 1987, and Professor Xu will be the conference chairman. This institute is also the headquarters for the Chinese Society of Luminescence which edits two domestic journals on luminescence.

The other notable aspect of this institute is its establishment of a national center for characterization and analysis. This center operates in much the same way as the National Submicron Facility at Cornell University, considering proposals from scientists and engineers throughout China for research which requires this facility. Details of the equipment in this facility will be given below.

. Compound Semiconductors

Most of the semiconductor work in Changchun is on optical devices, with heavy concentration on visible lasers and LEDs. Japan currently has 70-80% of the world's market of LEDs (over 3 billion LEDs are made in Japan annually), and China would like to enter this market.

The AlGaAs/GaAs system is the principal material chosen for visible LEDs with 35% Al in the active layer corresponding to an emission wavelength of 0.66 μm . They have routinely achieved efficiencies of 2-3%, which is satisfactory, but have not succeeded in reducing the cost to a competitive level. They are also working on GaP:N, for which they can also make good quality but too expensive diodes, and on GaN for which they, along with the rest of the world, have been unable to solve the type-conversion problem.

Another subject of some interesting work at Changchun is that of coupled-cavity amplifiers using Fabry Perot resonators, with GaAs lasers supplied by Shanghai or Beijing. (Note that they are not yet making semiconductor lasers at Changchun, although that is one of their goals.) They have achieved gain of 25 dB at 0.85 μm with this configuration, and are now initiating a new project on a traveling wave amplifier using phase matching.

Changchun is one of a small number of laboratories in the world (along with GM and Lincoln Laboratory in the U.S.) working on PbSnTe infrared lasers. They currently make infrared lasers operating between 10 and 13 μm (at $T=23\text{ K}$), tunable by varying injection current, pressure, or magnetic field, and are trying to make double-heterostructure devices (which has already been done in the U.S.) which would have a higher operating temperature.

At the other end of the spectrum, there is significant effort focused on wide band gap II-VI compounds such as ZnSe, with the hope of solving the type-conversion problem to make efficient p-n junctions for blue LEDs. They have made MIS structures which emit blue-yellow light under forward bias with good electroluminescent spectra (i.e., no deep-level emission), and MS (metal/semiconductor) devices which emit yellow light under reverse bias. However, the efficiencies for blue emission are still far too low to be useful, $\approx 10^{-5}$.

The institute is in the midst of a reorganization which suggests the importance they attach to compound semiconductors for future device work. Two departments will be combined, involving semiconductor lasers and integrated/guided-wave optics using III-V compounds and LiNbO_3 (dielectric waveguides, acousto-optic interactions, nonlinear optics, periodic structures). The integrated optics work will be directed by Mr. Yuan Yourong, who worked as a visiting scholar in my laboratory in Santa Barbara for more than two years. A separate department will work on the related materials problems, such as crystal growth, optical and electrical properties, defects and impurities, and basic physics of these materials.

. National Center for Characterization and Analysis

The facilities already assembled for this center are quite impressive. Much of it has been bought in the U.S., Japan, or Western Europe; they tend wherever possible to buy complete systems for characterization and analysis. Below I will describe this facility in some detail, not because such detail is important for its own sake, but to give the reader an accurate impression of the scope of this center and the level of sophistication involved.

- Room Temperature Photoluminescence: Chinese-built Ar⁺ ion and dye laser system with 1-m double grating monochromator.
- Low Temperature Photoluminescence: Nitrogen-pulsed dye laser, Oxford liquid helium cryostat with 7 T superconducting magnet, SPEX double monochromator, Products for Research photomultiplier coolers, all under computer control.
- Raman Spectroscopy: Jobin-Yvon JY T-800 complete Raman system with sample refrigeration system, Ar⁺-laser excited dye laser, He-Ne laser, Nd: YAG laser, photon counting system, uniaxial stress. Best Raman system in China.
- Nanosecond Fluorescence Time Resolution System: Flash lamp, large-aperture monochromator, photon counting system with time correlation.
- Picosecond Time Resolution System: Chinese monochromator and two separate laser systems:
 - mode-locked Spectra Physics Model 171 Ar⁺ ion laser with four dye lasers, and
 - high-power Lambda Physik excimer laser plus dye laser, with Kerr cell switch driven by Ar⁺ ion laser.
- Electron Paramagnetic Resonance: Varian "E-Line Century Series" complete system.
- X-ray Diffractometer: Rigaku rotating anode and double crystal diffractometers.
- Scanning Electron Microscope: Hitachi 50 keV SEM.
- Ion Implantation: Homebuilt 400 keV machine with extremely flexible source, capable of providing beams from solid, liquid, or gas materials covering most of the periodic table.

- Shanghai Institute of Metallurgy

Chinese Academy of Sciences
Shanghai 200050, People's Republic of China
Director: S. C. Zou

. Overview

This institute was established in 1929 to work on classical, macroscopic problems of metallurgy. In recent years, the focus of the institute's research has changed, and it has experienced great growth. Since the early 1960s, the emphasis in this institute has shifted from metallurgy to new materials such as semiconductors and magnetic materials with

emphasis on both discrete devices and integrated circuits. The size of the institute has also changed significantly, from a total staff of 70 in 1952, to over 1200 at present. Of these there are approximately 750 scientists and technicians including 40 professors and associate professors and 80 graduate students. Again, many of their people are studying abroad; at present there are five Ph.D. students studying outside of China.

Although the primary support received by all institutes of the Chinese Academy of Sciences is the government, this institute is developing strong relationships with manufacturing companies in and around Shanghai, and, to a much lesser extent, foreign companies. In particular, there are two optical fiber factories in Shanghai, and one factory manufacturing terminal and optical communications equipment; the Shanghai Institute of Metallurgy is providing the R&D support for this manufacturing activity with a strong attempt to transfer technology to these factories. In fact, my host for this visit, Professor Pan Huizhen, a renowned scientist who is in charge of the optoelectronics research at the institute, spends much of her time developing relations with industry for research support and technology transfer. She and I agreed that we had much in common!

There are now three main areas of emphasis in the institute:

- *Si LSI Microelectronics*, started in 1965. They have transferred to a local factory their 16 Kb EPROM and 4 Kb CMOS SRAM, and are currently working on a 16 bit microprocessor.
- *Functional Materials and Devices*. This is where compound semiconductors fit in, with a large effort on optical devices and a small but growing effort focused on HEMT. Other subjects of investigation in this section are magnetic bubble material, hydrogen storage material for the purification of hydrogen for semiconductor applications, and semiconductor sensors and transducers.
- *Corrosion*. (And I heard no more about corrosion.)

. Bulk Crystal Growth

The LEC crystal pullers were designed and built in this institute. They are currently growing one-inch boules of InP and semi-insulating GaAs (either undoped or co-doped). Etch pit densities are of order $10,000 \text{ cm}^{-2}$.

Horizontal Bridgeman (HB) is also used for GaAs doped with Si, Cr, and Te, and for high-purity GaAs. Etch pit densities are a factor of 10 less than LEC (1000 cm^{-2}), and they can control stoichiometry better by varying the As pressure. They have compared the microwave properties of FETs made on both substrates, and find them superior for devices made on HB. The problem with this material, however, is that the substrates are too small.

. MBE

Their MBE machine was received from Shenyang only a month earlier, so they have not yet grown by layers with it. However, they have been able to reach a vacuum of 10^{-10} Torr. Some layers were grown with this machine by Mrs. Li, the MBE group leader at the factory, which resulted in a paper presented at the 1984 MBE workshop in San Francisco. It is interesting to note, by the way, that Mrs. Li was a visiting scholar with Professor A. Milnes at Carnegie-Mellon University where she learned MBE technology; she is another example of a Chinese scholar whose institute is benefitting in its efforts to

initiate a MBE program in Shanghai.

Plans for this machine include the growth of GaAs on Si substrates, growth of GaAs on Ge on Si substrates, and GaAs/AlGaAs (on GaAs substrates) for HEMT and optical devices.

. High Speed Electronic Devices

During the "shake-down" period of their MBE machine, the electronic device group has started to "practice" HEMT fabrication with material supplied by Carnegie-Mellon University--no performance data were mentioned. However, it is clear that they intend to make HMET research a significant activity and already have ten researchers in their new HEMT group. They have also worked on a variety of other devices, including GaAs MESFETs with a tungsten silicide gate, a 18 GHz GaAs switch, a GaAs Varactor with ϕ 400 GHz, a Gunn diode operating at 8.6 mm, and a dual-gate FET with transconductance of 20-30 mS/mm.

. Optoelectronic Devices

The institute is working on a variety of optoelectronic devices, and has achieved respectable performance for several of them. These devices are made by LPE. Results will be summarized only briefly here.

- *High Efficiency GaAs/AlGaAs Solar Cells.* They routinely fabricate devices of 1 cm² area with efficiencies of 16-17% achieved routinely, 20% maximum. This compares favorably with the best reported worldwide: maximum 21-22%, but typical values of 12-15%.
- *High Radiance GaAs LEDs.* They have developed LEDs in both the edge-emitting configuration for higher speed, typically 50-70 MHz, up to a maximum exceeding 100 MHz and the Burrus configuration for high power output. They have been able to couple 100 μ W into optical fibers, which is modest compared to the state-of-the-art (e.g., Fujitsu in Japan and Codenol in the U.S., both of whom can couple 150-200 μ W into fibers.) These devices are now manufactured in a Shanghai factory.
- *InP LEDs.* Since 1981, they have been working on InP LEDs at both 1.3 and 1.55 μ m. They have achieved 1 μ W output power, and have coupled 50 μ W into an optical fiber. They have now set up a pilot line for the small-scale production of these devices.
- *InP/InGaAsP Lasers.* These devices are currently under development.
- *GaInAs/InP PIN Photodetectors.* These devices currently work at frequencies up to 30 MHz--the goal is 50 MHz. Hybrid integration with GaAs FET has been achieved.
- *Integrated Optics.* In the GaAs/AlGaAs system, they have been working on etched mirror lasers in parallel with my work, and have achieved comparable results. They are currently trying to make stripe geometry devices with etched mirrors, but efficiency is low for mirrors made by wet chemical etching. They are, therefore, building up a capability for reactive ion etching. A second LPE furnace

is being used for the InP system, for which they are working on the integration of an optical source (initially a LED, later a DH laser) with a heterojunction bipolar transistor (HBT). A third LPE system is used for InGaAs detectors. The ultimate goal for much of this work is a monolithically-integrated repeater for long distance optical communications.

. Characterization and Processing Capability

The institute appears to be reasonably well-equipped. An important facility is the Rutherford backscattering (RBS) laboratory, with a 2 MeV accelerator for RBS and channeling, manufactured by the National Electrostatic Corporation in Madison, Wisconsin. They are currently studying the formation of silicides on Si, and the interface between GaAs and Ge; future plans include superlattice studies.

A new reactive ion beam etching system (RIBE) has just been developed in this institute. They use CF_4 as the reactive gas, and can produce a 10-cm-beam diameter with energies between 100 and 1000 eV (below 100 eV the beam becomes unstable).

Another research program in the Institute of Metallurgy involves the use of lasers and flash lamps for annealing implant damage and recrystallizing amorphous material. A Q-switched ruby laser, both Q-switched and continuous wave (cw) Nd:YAG lasers, and a cw Ar^+ ion laser are all used to anneal the damage produced by B and P implants into Si, and Si implants into GaAs. These results are compared with rapid thermal annealing (RTA) using incoherent lamps for short time cycles. Much work on this subject has been carried out in Japan and the West for the last eight-ten years where it has generally been found that RTA gives superior device results compared with laser annealing, and I did not hear of any remarkable new results at this institute. However, they are working in some of the areas that are considered in the West to be most promising, such as the laser alloying of Au/Ge/Ni contacts on GaAs, and the use of scanned cw lasers to regrow polycrystalline Si-on-insulators (SOI). For example, they have produced single crystal grains as large as 30 μm , and have formed n-channel MOSFET devices, and complementary MOS devices on these grains.

Other characterization equipment includes deep level transient spectroscopy (DLTS), and several optical techniques: photoluminescence, photo-Hall effect, photocapacitance, and photo induced transient spectroscopy (PITS). For DLTS they have two systems, one Japanese and one Chinese, with better results obtained from the former.

- Shanghai Institute of Technical Physics

Chinese Academy of Sciences
420 Zhong Shan Bei Yi Road
Shanghai, People's Republic of China
Associate Director: Professor Liu

. Overview

This institute was founded in 1958 with its focus centered in the fields of solid state physics and electronics. They currently have approximately 500 people in total, with ten professors and 70 graduate students, mostly M.S.s. Since 1964, the emphasis has been in infrared physics and technology. There are three general areas of research:

- IR elements and devices, with work on Hg-doped Ge, InSb, HgCdTe, thermal IR detectors, CCD devices, and materials for IR optics. Some of this work will be described below.
- Applications to remote sensing, such as airborne multispectral scanners and two-dimensional imaging systems for medical and military applications. I think that this activity was extremely impressive; for example, I saw a thermal imaging system for medical diagnosis which had very sophisticated software, and which was comparable to equipment produced in the U.S. They are also doing some excellent work on multispectral scanners. In one activity, they are collaborating with William Collins, president of Geophysical Environmental Research, Inc. (GER), who makes a 64-band airborne spectrometer that does not scan. The airborne scanner made in Shanghai has only six bands, but obtains comparable results. The Chinese consider remote sensing to be an important field, and I was told they have launched 16 satellites to date (but I could not be told the location of their launching site, since they are not publicized). They also have graduate students in U.S. university departments known for strength in remote sensing, of which UCSB is one.
- Infrared physics, with emphasis on the physics of very narrow band gap semiconductors, and far infrared spectroscopy and detection.

One of the strengths of this institute is its experimental capability for investigating the properties of infrared materials. In particular, they have an excellent facility for Fourier transform spectroscopy, infrared absorption, photoluminescence, and Raman scattering. This spectroscopy laboratory has been designated an *Open Laboratory*, open to all researchers from China and abroad. (I was encouraged to come back as soon as possible.) The Chinese Academy of Sciences will entertain proposals from any investigators to do research using these facilities, and will fund those judged to be superior.

Another interesting aspect of this institute is the creation of a new department for technology transfer, which has thus far exported infrared devices in small quantities. For example, they have shipped several dozen pyroelectric detectors, which are considered to be superior devices on the world market, to West Germany. Another example of successful technology transfer from this institute to industry is the use of Si photodiodes in the budding Chinese camera industry.

My host for this visit was the associate director of the institute, Professor Liu, who spent a year at University of California, Santa Barbara as a visiting scholar with Professor Walker in the Department of Physics.

. Si Devices

One major area of activity in this institute is the development of Si detectors and CCD imaging arrays. They are making both one- and two-dimensional CCD arrays. A principal researcher involved in this research, Mr. Wu Zuoliang, was a visiting scholar in my laboratory between 1980 and 1982.

Thus far their CCDs have been developed for visible light imaging, but they are working on Si photodiodes with good UV response. The detectors used for these imaging arrays are silicide Schottky barrier devices, with a 1 μm depletion region, and a Pt silicide contact of thickness $\approx 20\text{-}100\text{\AA}$ to extend the device sensitivity to $\approx 6\text{ }\mu\text{m}$. However, their devices have a lower efficiency than those reported in the U.S.

. III-V Compounds

There is little work on III-V compounds except for the narrow band gap material InSb used for infrared detectors. Their material has very low background carrier concentrations, $<10^{14} \text{ cm}^{-3}$, which they export to other countries since it is believed to be the highest purity material available worldwide. They achieve this by multiple gas transports (≈ 500 times) of the starting material. The wafers are grown by Czochralski (not LEC since there are not serious pressure problems as with wider band gap III-Vs), and have etch pit densities $<100 \text{ cm}^{-2}$.

. Physics of Infrared Materials

The institute has a strong infrared measurement capability, and they are using it for detailed studies of HgCdTe and other narrow band gap materials. Principal equipment acquisitions are a Perkin-Elmer IR Spectrophotometer (Model 983), which is a new, modern instrument with computer processing, and a Nicolet Fourier Transform Spectrometer (Model 200SXV) complete system. This equipment is being used to carry out a systematic study of the infrared absorption of HgCdTe. They can measure absorption coefficients as high as $\approx 3,000 \text{ cm}^{-1}$ by polishing samples to thickness of $<10 \mu\text{m}$. By fitting their data to the Kane model, they believe they have the most accurate measurement of the energy gap of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ as a function of composition for x in the range of $0.165 < x < 0.4$. They also determine the intrinsic carrier concentration and effective masses; they find electron carrier concentrations less than 10^{14} cm^{-3} and measure $m_{hh}=0.55 m_0$. I believe this work to be of high quality on a subject which is currently receiving heavy funding from the Department of Defense in the U.S.

The Fourier transform spectrometer is being used for the study of local modes in a number of materials such as GaAsP, CdMnTe, Fe-doped Si, and HgCdTe. In addition, they have identified shallow impurities in some of these materials such as the shallow Li acceptor in CdTe.

Two other impressive laboratories (which I understand are part of the *Open Laboratory* described above) are a photoluminescence (PL) laboratory and a Raman scattering laboratory. Both labs have new equipment recently bought from the West. The PL laboratory uses a Chinese argon ion laser, a Jobin Yvon spectrometer with seven gratings covering the spectral range from UV to $14 \mu\text{m}$, an Oxford Instruments transfer-type liquid He cryostat, photon counting and phase sensitive detection. They are currently using this system to study the surface treatment of CdTe for use as a substrate for HgCdTe epitaxial layers. The Raman laboratory has a Coherent Radiation 5 W argon ion laser, SPEX double monochromator with a complete data processing system, cooled photomultipliers, etc. The system is brand-new, and is just being used for Si investigations.

- Shanghai Jiaotong University

1954 Hua Shan Road
Shanghai 200030, People's Republic of China
Host: Professor Chen Yi-Xin

. Overview

Professor Chen was the organizer of the Chinese Conference on Integrated Optics, and as such was my host in Shanghai providing the formal invitation for my visit to China.

He is a professor in the Department of Applied Physics at Jiaotong University, and its former chairman. He has been extremely active in developing the technological capability of this department, and is making significant progress; the department, and in particular his program, are focusing on important problems but progress is impeded by serious obstacles. Professor Chen is very knowledgeable concerning Western science and technology, but university funding for research and equipment appears to lag significantly behind the support available for the research institutes within the Chinese Academy of Sciences (such as those described above). Also, some of the equipment he needs is excluded for export to China by COCOM. Professor Chen was a visiting scholar for one year at University of California, San Diego with Professor William Chang; his research area is optoelectronics.

The Shanghai Jiaotong University is the primary technology-oriented higher educational facility in Shanghai (and, for that matter, one of the best in China), whereas basic arts and science are emphasized at Fudan University. American analogs might be M.I.T. and Harvard University, respectively.

. Optoelectronics

Professor Chen is working on a number of important problems, but in each case he is having difficulties due to equipment limitations.

- *Heterojunction phototransistors*, using InP/InGaAs grown by LPE. Their current problem is a background carrier concentration that is too high ($7 \times 10^{17} \text{ cm}^{-3}$), so that dark current is excessive.
- *Gratings*. They are modifying a Hitachi Model S450 SEM to write chirped gratings (i.e., gratings with changing period). This work is being done in collaboration with another researcher who spent time as a visiting scholar in the West modifying a SEM for e-beam exposure.
- *LiNbO₃ Fabry-Perot modulator*, with Ti-diffused waveguides. This device works at $f > 600 \text{ MHz}$. They want to butt-couple it to GaAs DH lasers, but have stability problems due to the coupled cavities. They are also planning to work on stepped ΔB directional couplers.
- *Ge avalanche photodiodes*. They use a guard-ring configuration by implanting Be, but their early devices have relatively low gain: 5-10.

- Jilin University

Changchun, People's Republic of China

Visitor: Professor Gao Ding-San

Professor Gao is head of the semiconductor department of Jilin University. Although time did not permit my visiting his department, he arranged to visit me during my stay in Changchun, and we were able to discuss optoelectronics research in our respective institutions. Professor Gao was accompanied by two colleagues, Professor Liu, who is in charge of device physics, and Professor Zhang, a former research scholar at Brown University who is now interested in semiconductor processing.

Professor Gao described Jilin University as a major semiconductor center. They work

on lasers (both GaAs and InP) using an LPE system that was commercially produced in China (and which gave them much trouble at first). They work on integrated optics and OEIC, trying to integrate lasers with FETs. They plan to make DFB lasers, and are setting up reactive ion etching (which Professor Zhang studied at Brown University). Professor Liu has worked on superlattices from a theoretical point of view doing LCAO calculations. In general, I got the impression that they have very ambitious plans, but are only beginning much of this work. As I saw in so many other laboratories, Professor Gao described a Chinese shift in policy which allows them to purchase laboratory equipment from the West, and they are doing so at Jilin.

- Zhejiang University

Hangzhou, People's Republic of China
Host: Professor Wang Ming-Hua

Professor Wang is a professor in the Department of Radio and Electronic Engineering, and currently serves as department chairman. He invited me to come to Hangzhou for several days to lecture on optoelectronics since that is one of their four areas of current research, and one that they intend to expand in the future. (The other three areas are communications, microwave and electron physics, and Si ICs.)

They are presently assembling several characterization and fabrication laboratories (including a clean room which is under construction), much of which is used for instruction. Professor Wang appears to be the most active faculty member, and is establishing a program to design and build a directional-coupler modulator for use at 1.2 GHz. This is a technology he learned as a two-year visiting scholar at the University of Tokyo with Professor K. Tada. He has just received a grant from the Ministry of Education to purchase an e-beam evaporator, a magnetron sputtering system, mask aligner, an LPE system, an optical isolation table and device testing system, and a high frequency oscillator.

Hangzhou also has a Jiaotong University, with interests in optical communications. Dr. Tynge Li of Bell Laboratories was invited to present a series of lectures there on optical communications and systems.

CONCLUDING COMMENTS

I hope that I have left the reader with an impression that a dynamic growth in compound semiconductor research and development is taking place right now in the People's Republic of China. They are just beginning to work in important areas such as MBE, RIE, MQW lasers, MESFET ICs, and HEMT technology, but they have not accomplished a great deal in these areas. They have been doing good, solid research in optoelectronics for a number of years, and they plan to expand this work considerably; many new laboratories, including clean rooms, are presently under construction. Due to a major shift in policy in China, doors are being opened to the West and the Chinese are importing as much high technology equipment as they possibly can. The U.S. government appears to be decreasing the barriers for at least some of this equipment, but there are still severe limitations being put on the Chinese. It has been my impression, formed during this three-week tour, that the Chinese are making very good use of their visiting scholar and study abroad programs, although there are, of course, some counter examples. Most recently, they seem to be sending younger men and women, including larger number of students, who will be the leaders of tomorrow. They are also increasingly asking their

hosts for financial support for these students and researchers.

The image of a "sleeping giant" slowly awakening is perhaps a good one, and when we consider the size of China's population, the implications of this are enormous. In my report I have emphasized the modern laboratory facilities they are constructing, as well as described their current progress in optoelectronics because the build-up of experimental capability with sophisticated measurement equipment suggests their potential for the future. In addition, there has been an emergence of consumerism and free enterprise throughout their country. For example, the government has allowed people to establish private business enterprises in the last few years, and my Chinese hosts and friends frequently commented that these shopkeepers and businessmen were "becoming rich." When we arrived at Beijing airport, we found it almost impossible to get our baggage to the customs inspection stations because of the incredible piles of Japanese color television sets that Chinese tourists and businessmen were bringing back from Tokyo and Hong Kong! I have read recently that the Chinese government thinks this is getting out of hand and is tightening the restrictions, but I would guess this is simply an oscillation about a curve which will continue to grow for many years, especially if encouraged by the West.

As the Chinese overtures to the West increase, as I expect they will, the U.S. will have to decide whether to help them move squarely into modernity or not. It seems to me that the prospect of this huge socialist nation becoming increasingly friendly with us, and being more strongly influenced by our technology and way of life is a very positive one. Fujitsu Electric recently concluded contracts for 2 billion yen to supply instrumentation and technical information to factories and plant engineering offices in China with the hope of obtaining twice that in contracts with China next year. It is my hope that interactions and collaborations between the United States and China on the technical level will also increase in the coming years.

ACKNOWLEDGEMENTS

I would like to thank Professor Chen Yi-Xin of the Shanghai Jiaotong University and Professor William Chang of the University of California, San Diego, for making this trip possible; all of the directors and administrators of the institutions visited for their unsurpassed hospitality; Dr. George Wright of the Office of Naval Research, Far East Liaison Office, for his help with this report; and Mr. Yuan Yourong of the Changchun Institute of Physics who was my guide for the entire trip in China, and who translated most of my seminars and talks. His assistance was invaluable.

PRESENT AND FUTURE SYNCHROTRON RADIATION FACILITIES IN JAPAN

Herman Winick

INTRODUCTION

I was very pleased to be invited by Takehiko Ishii to spend four months as a visiting scientist at the Institute for Solid State Physics (ISSP) of the University of Tokyo. This visit, cosponsored by Kazuo Huke of the Photon Factory, gave me an excellent opportunity to find out firsthand about the status and prospects for synchrotron radiation research in Japan.

This article summarizes my observations and discussions during this visit. It is the third in a series of reviews of synchrotron radiation research and facilities in Japan that have appeared in the *ONR Scientific Bulletin*. The first was a review I wrote that appeared in the *Scientific Bulletin* in 1978 [*Bulletin*, 3 (4), 1 (1978)]. This was updated by Leon H. Fisher in September 1982 [*Bulletin*, 7 (3), 1 (1982)]. These articles give much detailed information about the basic design parameters of presently operational facilities. In an appendix to this article, an update on the present status of these facilities is presented with particular emphasis on the Photon Factory, the largest and most capable facility [see *Scientific Bulletin*, 9 (2), 102 (1984)]. The interested reader is referred also to annual activity reports published by the SOR-Ring and Photon Factory laboratories and activity reports planned for 1986 by the UVSOR laboratory as well as to other references listed at the end of this article.

OVERVIEW

Synchrotron radiation facilities and research activities have grown significantly in the past few years. At the time of my last visit in October 1980, the only storage ring operating in Japan was the pioneering SOR-Ring (the first ring in the world to be designed and constructed as a dedicated synchrotron light source), operated by ISSP at the Institute for Nuclear Studies (INS) in Tanashi, Tokyo. The situation is now quite different. Synchrotron radiation research is now an established (and still growing) enterprise in Japan as can be seen from the following brief synopsis.

- Four fully dedicated light source storage rings are now in operation. Joining the venerable SOR-Ring are the 2.5 GeV Photon Factory (PF) at KEK, the 800 MeV TERAS ring at the Electrotechnical Laboratory in Tsukuba, and the 750 MeV UVSOR ring at the Institute of Molecular Science in Okazaki.
- About 1500 scientists are involved with research on about 45 operational experimental stations on these rings. Several more additional beam lines and experimental stations are in construction and planning.
- Four permanent magnet undulators and two superconducting wigglers have been built and used in Japan. Several more are being designed.
- A beam line is in construction on the recently completed 6-8 GeV accumulator ring (AR), which is part of the Tristan colliding beam project at KEK, and several more are being planned. Consideration is also being given to synchrotron radiation use of the 25-30 GeV Tristan main ring.

- The Nippon Telegraph and Telephone Corporation (NTT) has authorized construction of synchrotron radiation sources for soft x-ray lithography. Several other companies in Japan are considering such rings.
- Four or more groups are planning and proposing new dedicated rings, primarily low emittance rings optimized for insertion devices.
- I was told that the Ministry of International Trade and Industry (MITI) has announced that it will receive proposals by the end of January 1986 for new soft x-ray lithography instrumentation to be funded in FY86. This program could provide up to 70% of the construction cost of new storage rings for this purpose.

Synchrotron radiation research is clearly alive and well in Japan. The excitement, involvement, and interest of the scientific community was also evident to me at two major meetings that I attended. The first was a meeting of the Japanese Physical Society at the University of Chiba in September 1985. At this meeting there were two symposia and one other session relevant to synchrotron radiation. The titles were:

- the Development of Research Using Synchrotron Radiation X-rays,
- the Generation of Short Wavelength Light with Applications to Atomic and Molecular Processes, and
- Synchrotron Radiation and VUV Spectroscopy.

Each of these symposia was attended by over 200 scientists and there was much lively discussion. I was requested to make some comments about the present status and future plans for synchrotron radiation research in the U.S.A.

Along with about 250 scientists, I also attended the Photon Factory Users Symposium held at the Komaba campus of the University of Tokyo on 3 and 4 November 1985. There were over 100 poster presentations and about ten talks reviewing instrumentation development and scientific results in different areas. There were also talks about ring performance and plans for new insertion devices, new beam lines, and new rings.

At these meetings and on other occasions, I received many invitations to visit universities and laboratories and deliver lectures on insertion devices, present and planned facilities in the U.S., research applications of synchrotron radiation and related topics. I visited seven institutions, delivered six lectures, and had many informal discussions with individuals and groups.

Based on these interactions and observations during my visit, it is clear to me that activity in the synchrotron radiation field in Japan is comparable to that in the U.S.A. and Europe. Thus, there is much mutual benefit that scientists from these different areas can derive from a detailed awareness of each others' present work and future plans. Exchange of information and personal visits among users of synchrotron radiation is already happening to a significant extent, but less so among those responsible for the operation of present facilities and the design of future facilities. I found that many Japanese scientists involved with developing plans for future rings are eager to learn more about the work of groups pursuing similar activities in the U.S.A., where planning is proceeding for 6 GeV and 1-2 GeV sources, and Europe, where the European Synchrotron Radiation Facility (ESRF), a 5-6 GeV synchrotron radiation source, was recently approved for construction in Grenoble, France, by several European countries. Although some small meetings on the design of such sources have been held in Japan, most of the work is being done by individuals or small

groups at different institutions. One Japanese group is planning an international workshop in 1986 on the design of low emittance rings optimized for insertion devices.

FUTURE SYNCHROTRON RADIATION FACILITIES IN JAPAN

There is now a ferment of activity in the planning and proposing of new storage ring light sources in Japan. These fall into two general categories:

- low energy storage rings for industrial purposes, and
- medium and high energy rings with low electron beam emittance optimizing for wiggler and undulator insertion devices.

These rings would be used for basic and applied research.

It may seem surprising that there is a strong push for the construction of new rings for basic and applied research considering the fact that there is still room for additional beam lines and experimental stations on three of the four presently operating facilities in Japan. The reason for this is the realization in Japan, as well as the U.S.A., Europe, and the Soviet Union, that radiation with orders of magnitude higher brilliance can be produced by undulator insertion devices in rings that have an order of magnitude or more lower electron beam emittance than do any present rings, including the lowest operation. Furthermore, all present dedicated light source rings around the world have been built primarily as bending magnet sources, with relatively few straight sections available for insertion devices. The new rings being proposed have ten to 30 straight sections for the wiggler and undulator insertions. Of course, these new rings would also have many bending magnets which could also be used as sources, but first priority would be given to the insertions.

The following is a listing and brief description of the new ring projects of which I became aware during my visit.

- Nippon Telegraph and Telephone Corporation (NTT)

On 31 October 1985, NTT held a groundbreaking ceremony at their LSI Laboratory in Atsugi, Kanagawa prefecture, to initiate their project to construct synchrotron radiation sources. The project is in their x-ray lithography division headed by Toha Hayasaka. The person in direct charge of the project is Toyoki Kitayama and Teruo Hosokawa is the leader of the design team. I was told that eight people have been working on the project for the past two years.

They plan to construct a 550 MeV ring with superconducting bending magnets operating at 3.5 T (critical energy = 704 eV). This ring would be in the shape of a racetrack with two long straight sections, primarily for RF and injection. They also plan to construct an 800 MeV synchrotron/storage ring with conventional bending magnets. If this ring had the usual 1.2 T bending magnet field, the critical energy would be 510 eV. This ring would be used as a light source on its own and also as a possible injector for the superconducting ring. A 15 MeV linac would be the injector for the conventional ring and also a potential injector for the superconducting ring. Their goal is to store 500 mA in both rings. The main purpose of the superconducting ring is x-ray lithography, whereas the synchrotron/storage ring could also be used for materials studies and other purposes.

The design will be done mostly by the NTT team. Hitachi will construct the superconducting ring and Toshiba will construct the conventional ring. A three-year construction period is planned.

My feeling, and the feeling of many Japanese scientists with whom I spoke, is that this is a very ambitious and perhaps risky project. The main technical concern is the low energy injection. They are aware of the possible problems with injection at 15 MeV into the superconducting ring, which is why they are also planning the alternative of using the synchrotron as a higher energy injector. If low energy injection into the superconducting ring is successful, it would result in a very compact facility since the superconducting ring is rather small (circumference about 30 m). This is an important consideration in making x-ray lithography an important industrial tool. The various groups involved in the project recognize that they have little experience in the design and construction of electron storage rings. They are training personnel and have arranged for consultants from synchrotron radiation facilities now in operation.

[The NTT project is quite similar to the COSY (compact synchrotron source) under development in West Berlin by the BESSY group and the Fraunhofer Institute for Microfabrication Technology (IMT), which is located on the BESSY site. The BESSY ring is now used extensively for lithography and the IMF, headed by Anton Heuberger, is pushing the COSY project very hard. They expect to have a first prototype of their industrial synchrotron source ready for injection tests in March 1986. It will have normal magnets and a 50 MeV microtron injector. They aim to store 300 mA in this ring. A new company, COSY Microtech, has been formed on 1 January 1986, for the purpose of marketing industrial synchrotron sources. They expect to announce prices and delivery dates for these products around March 1986. They expect to have the first prototype of the superconducting version, perhaps with very low energy injection, (using a combination of betatron and synchrotron acceleration in the superconducting ring) in operation by the fall of 1986.]

- ISSP/KEK New Light Source Project

A 1.0 GeV low emittance ring with ten to 13 straight sections for insertion devices is being designed as a joint project by the Institute of Solid State Physics (ISSP) of the University of Tokyo and the Photon Factory at KEK. The main proponent of this facility is T. Ishii, director of the Synchrotron Radiation Laboratory operated by ISSP. The injector will be the Photon Factory 2.5 GeV linac which has a 1 GeV takeoff point. The design of this ring has evolved over the past two years, and it is probably the most detailed proposal for a new source in Japan.

This project began as an ISSP project called Super-SOR, an outgrowth of the activities at the ISSP-operated 380 MeV SOR-Ring at the Institute for Nuclear Study in Tanashi which has been in operation for about ten years. Partly because adequate land could not be identified close to present ISSP operations in the Tokyo area, agreement was reached between ISSP and KEK for the facility to be located at KEK. The ISSP group will build one or more VUV/soft x-ray beam lines at the Photon Factory with the intention of eventually moving these to the new ring. Two ring designs are now under consideration; one with 16 to the new ring. Two ring designs are now under consideration; one with 16 segments and one with 12. (One segment is that part of the ring between long straight sections.) The main design parameters and operation modes of these two designs are summarized in Tables 1, 2, and 3 taken from the *Technical Report of ISSP, Ser A, (1607)*, December 1985, by Takehiko Ishii and Goro Ioyama. The ring is not yet approved for

construction. Figure 1 shows the proposed location at KEK.

- Kansai Synchrotron Radiation Source (KSRS)

A group based at Osaka University is proposing the construction of a 6-8 GeV ring together with a 1-2 GeV ring at the Nishi-Harima technopolis (industrial park complex) near Kobe. Prominently involved with promoting the project are Toshio Mitsui and Taizo Sasaki, the recently retired director of the Photon Factory. Both are on the Faculty of Engineering Science of Osaka University. The basic motivation is to provide advanced synchrotron radiation facilities based on low emittance rings optimized for many insertion devices.

A planning group consisting of five persons, including Mitsui and Sasaki, has been formed with the backing of many faculty members at universities in the Kansai area (Kyoto-Osaka-Kobe). The chairman of the planning group is Masao Kakudo, president of the Himeji Institute of Technology, a chemist and crystallographer, and also the retired director of the Institute of Protein Research of Osaka University.

The KSRS facility would be the centerpiece of a proposed technopolis centered at Nishi-Harima. The proposal for this technopolis has been approved by the national government and funding is now being sought from various governmental and industrial sources. The Hyogo prefectural government is expected to provide the land and is now providing funds to promote the technopolis and the KSRS. The total budget (assuming no cost for land) for the technopolis is estimated at about 10.0 billion yen with about 4.7 million yen for the KSRS.

Detailed designs for the storage rings have not yet been developed and the personnel required to produce these designs does not exist at Osaka. It is assumed that such personnel would be attracted to come to the project (e.g., from KEK after Tristan) if the funding for the facility is arranged.

Figure 2 shows the general location of the proposed facility and Figure 3 shows a possible layout.

OTHER PROPOSALS

Several other groups are working on proposals for future synchrotron radiation sources. Mostly, these are in earlier stages of development than the above mentioned proposals. Here are some details.

- The Institute for Physical and Chemical Research (Riken), Saitama prefecture, is proposing a 6 GeV ring for a technopolis near Nara. One accelerator scientist, Masahiro Hara, is working on the plans for the facility.
- A group at Hiroshima University under the direction of Yukitomo Komura is proposing a 3.0 GeV synchrotron radiation source. Y. Sumi from Hiroshima University and H. Yoshida from INS have developed a fairly detailed design for a synchrotron/storage ring/pulse stretcher facility with a proposed construction budget of 1.42 billion yen. The proposed injector is a 1 GeV linac. Other types of facilities are also under consideration including an FEL ring.
- A group at Tohoku University (Sagawa, Namioka) is considering a low energy ring.

- Storage rings are being considered for a technopolis in Yamagata prefecture.
- Some private companies are considering the construction of small storage rings for sale to other companies for use in x-ray lithography and free electron laser applications. In particular, the Ishikawajima-Harima Heavy Industry Company, Ltd., of Tokyo had two people at the Photon Factory to learn about storage ring design and technology.

Most of the above described proposals compete for national government funding with other proposals for major accelerator based research facilities, such as the following.

- Gemini project. Proposal by KEK for a heavy ion facility using the 12 GeV proton synchrotron.
- Proposal by the Laboratory of Nuclear Science of Tohoku University in Sendai for a 1 GeV linac and pulse stretcher ring for nuclear physics.
- Proposal by the Research Center for Nuclear Physics of Osaka University for a cyclotron for nuclear research. It would accelerate protons to 300 MeV and alpha particles to 340 MeV.
- Tristan Phase II. Proposal by KEK for raising the energy of the Tristan main ring to about 30 GeV.

ACKNOWLEDGMENTS

It is impossible for me to list the names of all of the people with whom I interacted in many pleasant and instructive ways during my four-month stay in Japan. I look forward to continued communication with them and to welcoming them to Stanford University. Special thanks must go to my primary hosts, Kazuo Yuke and Takehiko Ishii, for their excellent arrangements, hospitality, and friendship and for their patient explanation of Japanese ways.

REFERENCES

Papers describing the SOR-Ring, Photon Factory, UVSOR and the ISSP/KEK New Light Source Project were presented at the Workshop on Construction and Commissioning of Dedicated Synchrotron Radiation Facilities held at Brookhaven National Laboratory in October 1985. The proceedings will soon be available from the National Synchrotron Light Source at Brookhaven.

Takeshi Namioka, VUV/Soft X-Ray Spectroscopic Facilities at the Synchrotron Radiation Laboratories in Japan; *Proceedings of the U.S.-Japan Seminar on Ultraviolet Photobiology and Spectroscopy Using Synchrotron Radiation* held at Brookhaven National Laboratory, October 1985. (To be published in *Photochemistry* and *Photobiology*.)

Many contributions from Japanese synchrotron radiation laboratories, including a description of the proposed KSRS facility, were presented at SRI-85, held at Stanford University in July 1985; proceedings to be published as a special issue of *Nuclear Instruments and Methods*.

APPENDIX

PRESENT STATUS OF OPERATIONAL SYNCHROTRON RADIATION FACILITIES IN JAPAN

- SOR-Ring (SRL-ISSP)

During my stay in Tokyo, I visited this facility several times and had discussions with the director, Takehiko Ishii, and several of the staff including Goro Isoyama, Akito Kakizaki, Y. Miyahara, Tamiko Mori, M. Taniguchi, and S. Suga. The total staff for this facility consists of five scientists and two technical associates for the solid state group, and four scientists and three technical associates for the machine group. The total budget for operation in FY84 is about 50 million yen, not including staff salaries.

The main activities of the staff are the operation of the present facility, research at the SOR-Ring and at the Photon Factory, the design of new beam lines for the PF and the design of a new 1.0 GeV storage ring proposed for construction at KEK as a joint ISSP-KEK project.

The present facility operates ten or more hours per day, four days per week, for a total of about 1800 hours in 1984. Five beam lines and four active monochromator systems served a total of 119 scientists in 1984. Although it is the oldest storage ring in Japan, having started routine operation for experiments in FY76, it is still a very productive facility. A main limitation continues to be the severe lack of experimental hall space. If the proposed 1.0 GeV ISSP/KEK New Light Source Project is approved for construction, which may occur in the next two-three years, operation of the SOR-Ring will be cut back and eventually terminated due to the need to shift staff to the new project.

Injection to the SOR-Ring is at 308 MeV, 1 Hz from the 1.3 GeV electron synchrotron at INS during which users must evacuate the experimental hall. Typically, it takes about 15 to 30 minutes to accumulate 150 to 250 mA after which the energy is raised to 380 MeV. The lifetime at 200 mA is about four hours and three fills per day are provided. Ring performance has improved continually over the past several years, with improvement of the vacuum system, injection efficiency, and introduction of single bunch operation. A prototype permanent magnet undulator was tested in this ring, primarily to gain experience for the design and construction of Photon Factory undulators.

The monochromators are a Seya-Namioka monochromator covering the range 30-300 nm, a 2-m modified Rowland monochromator covering the range 80-40 nm, a plane grating monochromator covering the range 2.5-120 nm and a 2.2 m modified Wadsworth monochromator covering the range 50-260 nm.

- Photon Factory (KEK--Tsukuba)

Although I spent several weeks at the 2.5 GeV Photon Factory (PF), I still felt that I did not have enough time to see all that should be seen of this most impressive facility which now serves over 1000 scientists on nine main beam lines equipped with about 27 operational experimental stations. Tables 4-6 summarize the properties of these stations. Two of these beam lines are illuminated by very powerful insertion devices; a 3-pole 5 T superconducting wiggler and a 4-m long, 60 period soft x-ray undulator. More beam lines and insertion devices are in design and construction. The facility layout is shown in Figure 4.

The ring operates for about 2600 hours per year and routinely stores 150 to 250 mA with lifetime up to 30 hours at 150 mA. The ring operates on a two-week cycle from Wednesday of one week through Saturday morning of the next week. Seventy percent of the time is allocated to users; the initial eight hours are used for machine tuning and the remaining 64 hours are used for accelerator study on both the linac and ring. The net user time is typically in excess of 90% of the scheduled time.

. First Impressions of the PF

My first impression confirmed expectations that the PF is a well-conceived, well laid out facility with a comfortable working environment and adequate space for both experimenters and those working on the ring. This is in contrast to the situation at SSRL where we started parasitic operation in May 1974 with a single small building about adequate for one beam line equipped with five monochromators and experimental stations. Since then we have been putting up new buildings for new beam lines, support facilities and offices, and never seem to have enough room. The large PF experimental hall with its adjoining rooms for support activities, plus the available space inside the ring tunnel and in the building surrounded by the tunnel, greatly facilitate the work of experimenters and machine staff. Although this space looks generous now, it will probably be just marginal or barely adequate when the PF reaches its full complement of beam lines, experimental stations, insertion devices, staff and users.

An especially nice touch in the layout of the facility is the gallery passageway from the office building to the control room. It affords an excellent overview of the experimental floor and has many photographs and other exhibits above the windows to aid in explaining the workings of the ring and experiments to visitors. I was amazed at the large number of visitor groups that come through the PF. On most days there seemed to be one or two groups of ten to 30 people touring the facility. I imagine that without this gallery these visits would cause much disturbance to experimenters and facility staff.

I concentrated most of my time with the light source group headed by Kazuo Huke, but I also had brief visits with the injector linac group and the instrumentation group. I feel I would need several more weeks to adequately learn about the many developments in these other groups, particularly the recent work in instrumentation and applications. I interacted with so many people in all of these groups that it is not possible to list them all. The names of all the PF staff are conveniently given on the organization chart in the annual PF Activity Report.

The obvious success of the PF and the growth in the number of experimental stations and outside users has also caused some problems. In particular, the scientific staff, especially those in the instrumentation group which provides most of the assistance to outside users, has experienced a large increase in workload. The growth in experimental activity at SSRL has put similar pressure on our scientific staff. They also find that they spend so much time helping users, and on other facility responsibilities, that very little time is left for the research they would like to do. This is an important problem that must be addressed by facilities like SSRL and the PF. The long-term success of these facilities depends to a large extent on the quality of the scientific staff. To attract the best scientists, and to encourage their continued scientific development, they must have significant opportunities for research. I had several discussions with individuals and groups at the PF about this problem and some of the ways we have addressed it at SSRL.

. Visits to the PF Control Room

I spent many hours in the PF control room observing the behavior of the ring (and also the behavior of the machine physicists, which is even more interesting). It is clear to me that this group has much to be proud of, having designed, built and commissioned a very capable light source, now serving over 1000 scientists from all parts of Japan. The ring routinely stores about 200 mA which can be accumulated in just a few minutes at a 1 Hz injection rate from the 2.5 GeV linac. After conditioning the vacuum system with many weeks of running last spring, the lifetime was superb, reaching 30 hours at 150 mA.

Improvement in performance in the near future is likely to come from work now underway and planned on beam instabilities and photon beam steering, and also in the use of positrons as discussed in more detail later. In the longer term, the plans described by M. Kihara at the Users Symposium to reduce the electron beam emittance seems to me an important improvement which will increase the brilliance of all PF beams, increasing experimental capabilities.

Perhaps the most impressive feature of the PF is its full energy injector. I toured this fine accelerator, with its newly operational positron source, with Jiro Tanaka, who is justifiably proud of it. I was envious watching how quickly the injector could fill the ring to 200 mA and how advantageous it is to not change the ring energy. During part of the time I was there the storage ring vacuum was poor due to the installation of new chambers. This is a problem common to all rings. With a full energy injector, the PF staff was able to clean the vacuum system rapidly, using frequent injection to keep a large and essentially constant stored current for many hours at full operating energy, in spite of the short lifetime.

. Positrons at the PF

The trapping of positively charged fine particles or ions by the negatively charged electron beam is a pernicious problem in many storage rings. During my visit, the PF exhibited behavior similar to that observed in SPEAR and many other rings; namely the sudden reduction in lifetime from many hours to a few hours, or even a few minutes. Although there are ways to reduce the frequency with which these lifetime reductions occur, the only real cure is to switch from electrons to positrons, since positrons repel positively charged particles.

When I arrived in Japan, I was pleased to learn that positrons recently became available from the PF linac and that injection of positrons into the PF ring was planned. I made it a point to be at the PF during these tests at the end of the December 1985 run. I was impressed with the skill and efficiency with which the staff carried out these tests. The large number of polarity reversals were carried out in about six hours and the first stored positron beam was achieved a few hours after the linac crew started to deliver positrons to the PF ring. After another few hours of tuning the injection rate, it was possible to accumulate 5.5 mA in about two hours. This was about all that could be expected with the present injection conditions. Improvements planned in the next few months should result in a large increase in accumulation rate so that a direct comparison could be made with electrons at high currents. Based on our experience at SSRL, and also experience at Orsay and elsewhere, I expect that with high currents of positrons in the PF there will be no abrupt decreases in lifetime; the average lifetime should be longer and the photon beams should be more stable. Users will probably never want to see electrons again!

The availability of positrons is, of course, a benefit from the Tristan high energy physics program. The 6-8 GeV accumulator ring (AR) is now storing positrons as well as

electrons, an important milestone in the ambitious Tristan project. The planning that started more than 10 years ago for a powerful injector that could serve the needs of the PF and Tristan has now come to fruition. However, sharing an injector with the AR is a new fact of life for the PF staff which now has to more carefully schedule injection and operations in general. At present this sharing is complicated by the fact that the linac can only serve either the PF or the AR at any one time. The situation will be much improved when sharing on a pulse-to-pulse basis is possible.

. Higher Energy Rings at KEK

I walked around the accumulator ring (AR) with Masami Ando and saw the many places where beam lines could be constructed. I also saw the experimental hall that has been completed for synchrotron radiation beam lines, the first of which (a bending magnet line) is now in construction. Several additional beam lines from bending magnets and insertion devices are planned, using both the electron and positron beams in the AR and some thought is being given to the use of the 25-30 GeV Tristan main ring, scheduled for first stored beam at the end of 1986.

I was particularly interested in the use of these higher energy rings because at SSRL we are giving much thought to ways in which we could utilize the 5-15 GeV PEP ring which has been in operation for colliding beam physics for several years.

. PF Insertion Devices

Because of my particular interest in insertion devices, I had many discussions with T. Yamakawa about the PF wiggler and with H. Kitamura about the undulator. These operational magnets produce two of the most powerful synchrotron radiation beams in the world. The superconducting vertical wiggler (wavelength shifter) now operates fairly routinely up to 5 T, although the stored current and lifetime are somewhat reduced with the wiggler on. It is unique in the world in producing a vertically polarized photon beam. This feature, combined with its high critical energy (up to 21 KeV), has opened new experimental possibilities for PF users. The permanent magnet undulator (period length=60 mm, 60 periods) produces the brightest soft x-ray beam in the world and now serves two operational stations. The PF ring can accommodate several more insertion devices, some of which are now being planned. One or more of these will be multipole permanent magnet wigglers, similar to the 54 pole device now in operation at SSRL.

- TERAS (Electrotechnical Laboratory, Tsukuba)

I visited the TERAS ring and received a comprehensive tour from the director, Takio Tomimasu and one of the staff scientists, Tetsuo Yamazaki. This ring now operates routinely at 500 MeV but has reached 700 MeV and is expected to reach 800 MeV. The maximum injection energy is 300 MeV (due to present limitations in pulsed magnets) from the TELL 400 MeV linac.

The ring operates 24-hours per day, five days each week, with one injection per day. It provides an impressive 5000 hours of user beam time per year. Typically, 130-140 mA is accumulated in about 30 minutes and the beam lifetime is about ten hours at 200 mA. All 17 bunches are filled and no ion collection effects have been observed with total currents up to 150 mA. After 24 hours about 10 mA remains and the ring is refilled.

Two VUV monochromators are now in use. One is a plane grating type covering the

range from 2-8 nm. The other is a toroidal grating device covering the range from 10-50 nm. There is also one monochromator working in the long wavelength region up to 600 nm. In addition, one port is used for work on photometric standards and one for soft X-ray lithography. By the end of 1985, two more monochromators (a Grasshopper and a Seya-Namioka) will be on line bringing the total number of operational stations to seven. For lithography work, a simple and effective system of rocking the electron orbit vertically has been developed in order to spread the photon beam vertically to provide uniform exposures of masks.

A permanent magnet undulator (period length=80 mm, 17 periods) has been completed, installed, and tested in the TERAS ring. This device will produce high brilliance photon beam down to 20 nm when TERAS reaches its expected maximum energy of 800 MeV. In the future, work with optical klystrons and free electron lasers is planned in TERAS.

About 20 ETL scientists and ten from outside ETL use the facility. The total technical and scientific support staff for TERAS numbers six persons, with occasional help from others. These same six persons also support the linac, a pion channel, and the test ring described below.

A small storage ring is nearing completion at ETL. It is a test ring whose primary purpose is to learn about the operation of compact rings for lithography. The bending magnets can reach 1.0 T and have a bending radius of 0.7 m, corresponding to a maximum electron energy of 210 MeV. Injection will be studied at lower energies to determine how low an energy can be effectively used to inject into such a ring. The transport line to this ring is now being completed and first injection trials are expected by the end of January 1986. In the future, the bending magnets may be replaced with four Tesla superconducting magnets.

Future plants at ETL also include the development of high gradient linac structures so that compact injectors can be made for such rings, the use of the test ring as a pulse stretcher for the linac and recirculating the linac beam to increase the electron energy.

- UVSOR (Institute of Molecular Science, Okazaki)

In a brief visit to Okazaki, I met the director of UVSOR, Hiroo Inokuchi, and toured this facility with Toshio Kasuga and Makoto Watanabe in charge of the light source and measurements systems respectively. I was given information about several of the beam lines by scientists from IMS and other institutions involved with their development and use.

The ring, delightfully situated under tennis courts, has already operated up to 750 MeV. Recently, it has operated routinely at 600 MeV because most present users prefer that energy to minimize problems with harmonics and heating of optical components. Also, the primary instrument needing high energy photons, a double crystal monochromator, was damaged and is not now operational.

Injection is at 600 MeV from a synchrotron and typically it takes a few minutes to accumulate 100 mA. Shielding around the storage ring is minimal, providing convenient access to beam line equipment. Users evacuate the experimental hall during injection. The maximum stored current achieved was 330 mA, at which point a glass window in a beam line cracked.

Ion collection effects have been observed, causing an increase in beam size and also an increase in lifetime due to decreased Touschek scattering. When the beam is enlarged due to ion collection or use of a skew quadrupole, the lifetime is about two hours at 100 mA, limited by the Touschek effect and Coulomb scattering. Single bunch operation has been used for timing studies. Up to 40 mA has been achieved in a single bunch during machine studies. Typically, single bunch currents of about 10 mA are supplied to users due to the long filling time in this mode.

Longitudinal coupled bunch instabilities due to parasitic resonances in the RF cavity have been observed and can be minimized by adjusting the cavity temperature. The installation of active dampers is planned for 1986.

Permanent magnet undulator (period length=60 mm, 35 periods) and a 4 T superconducting 3-pole wiggler (wavelength shifter) have both been operated in UVSOR, and a second undulator is planned.

Nine monochromators have been completed and installed and five more are in construction. Table 7 summarizes the main characteristics of these monochromators. The ring has a capacity for more than 20 beam lines including three from insertion devices.

The facility stored its first beam in November 1983 and operation for experiments began in September 1984. The total cost of the light source and 14 experimental stations is about 2.2 billion yen. The buildings for the facility cost about 1.7 billion yen and the annual running cost is about 400 million yen. All of this does not include staff salaries. The staff consists of a director, two associate professors, two research associates, six technical staff, and an adjunct associate professor.

The status of the ring and the work on each of the beam lines was reviewed at a half-day Users Symposium that I attended on 2 December 1985. The first activity report is planned for publication in the spring of 1986. In 1984, four proposals for use of the facility were received. A total of 49 proposals had been received from January to October 1985. Operation for this fiscal year is expected to be a total of 37 weeks with 40 hours per week available for users and eight hours per week for machine studies. Two injections per day are provided. At present, no companies are engaged in work at UVSOR but some have expressed interest. A policy for industrial use is being worked out.

Future plans include the installation of a second undulator in the spring of 1986, additional beam lines, raising the injection energy to 750 MeV to facilitate routine operation at that energy, FEL work using the ring at 300 MeV and a small ring (200-300 MeV) for long wavelength experiments in photochemistry.

Figures 5 and 6 show the layout of the facility.

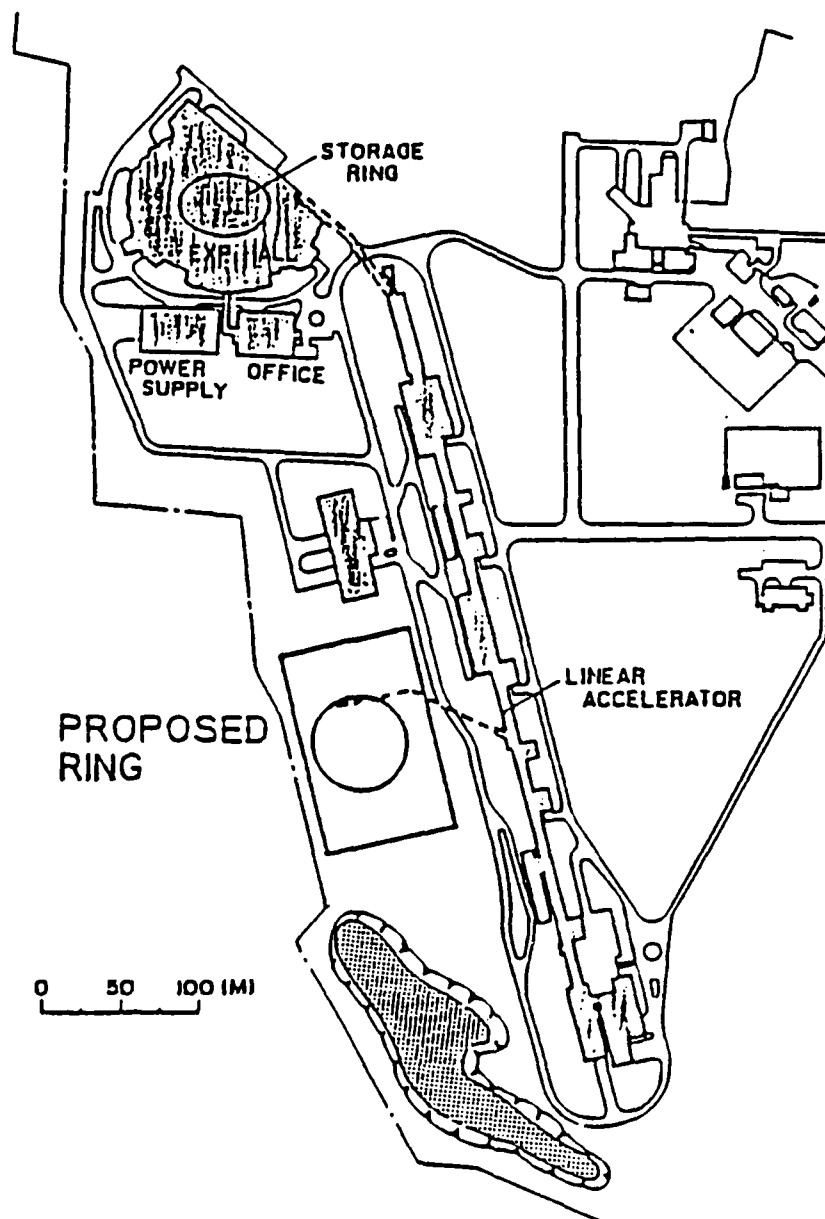
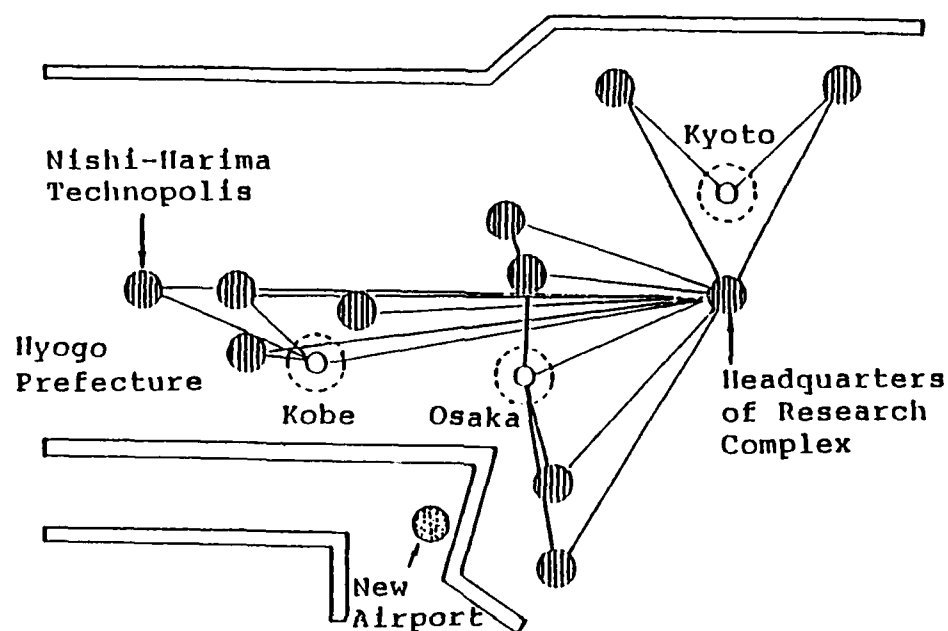


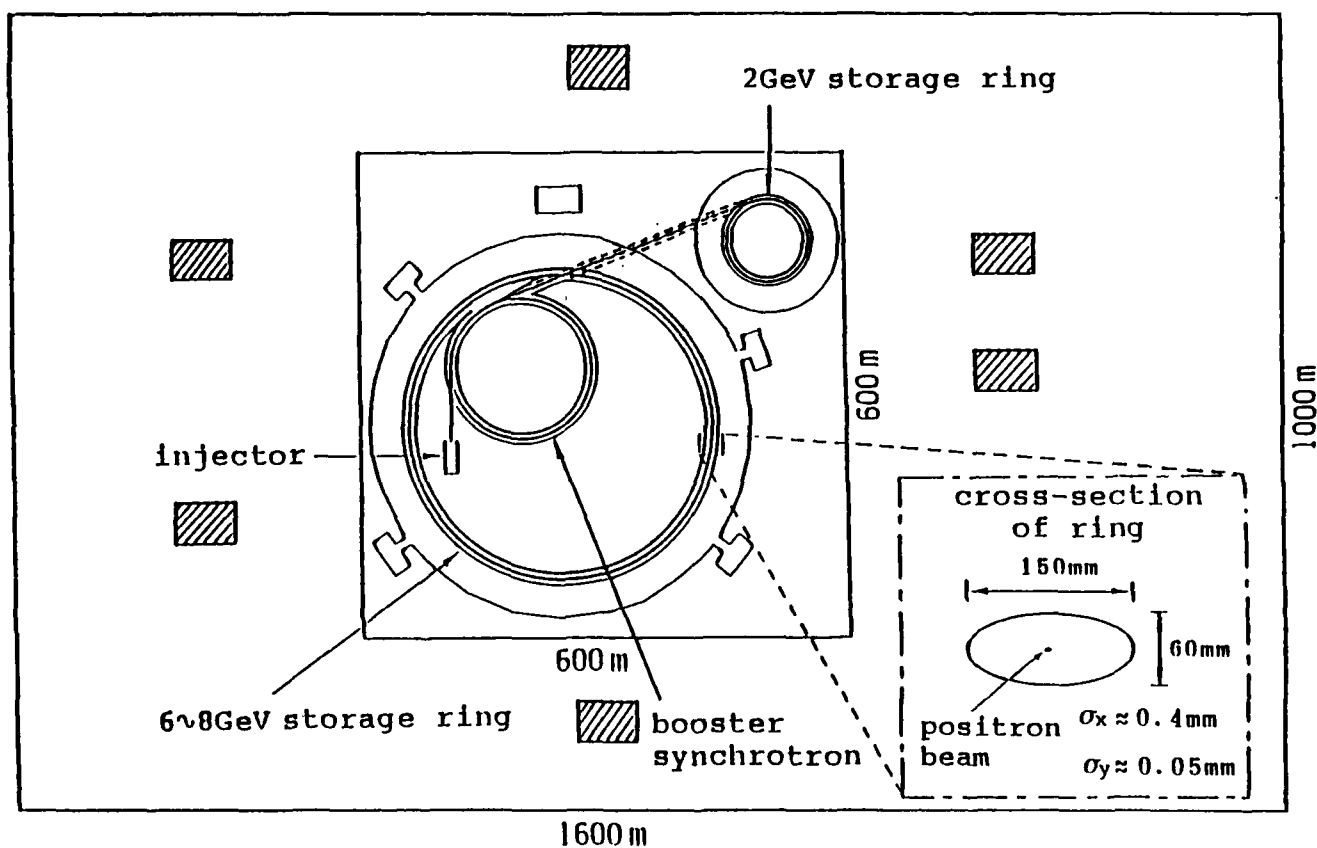
Figure 1. Plan view of the Photon Factory and the location of the new ring.

[Taken from the "ISSR-KEK New Light Source Project," T. Ishii and Itoyama. *Technical Report of ISSP, Ser A, (1607)* December 1985.]



⊙ : Laboratory assembly (including planned one)

Figure 2. (Taken from "6 GeV Synchrotron Radiation Project in Japan," T. Mitsui. Presented at SRI-85, July 1985 at Stanford, California. To be published in *Nuclear Instrumentation and Methods*.)



▨ : related laboratory

Figure 3. (Taken from "6 GeV Synchrotron Radiation Project in Japan," T. Mitsui. Presented at SRI-85, July 1985, Stanford, California. To be published in *Nuclear Instrumentation and Methods*.)

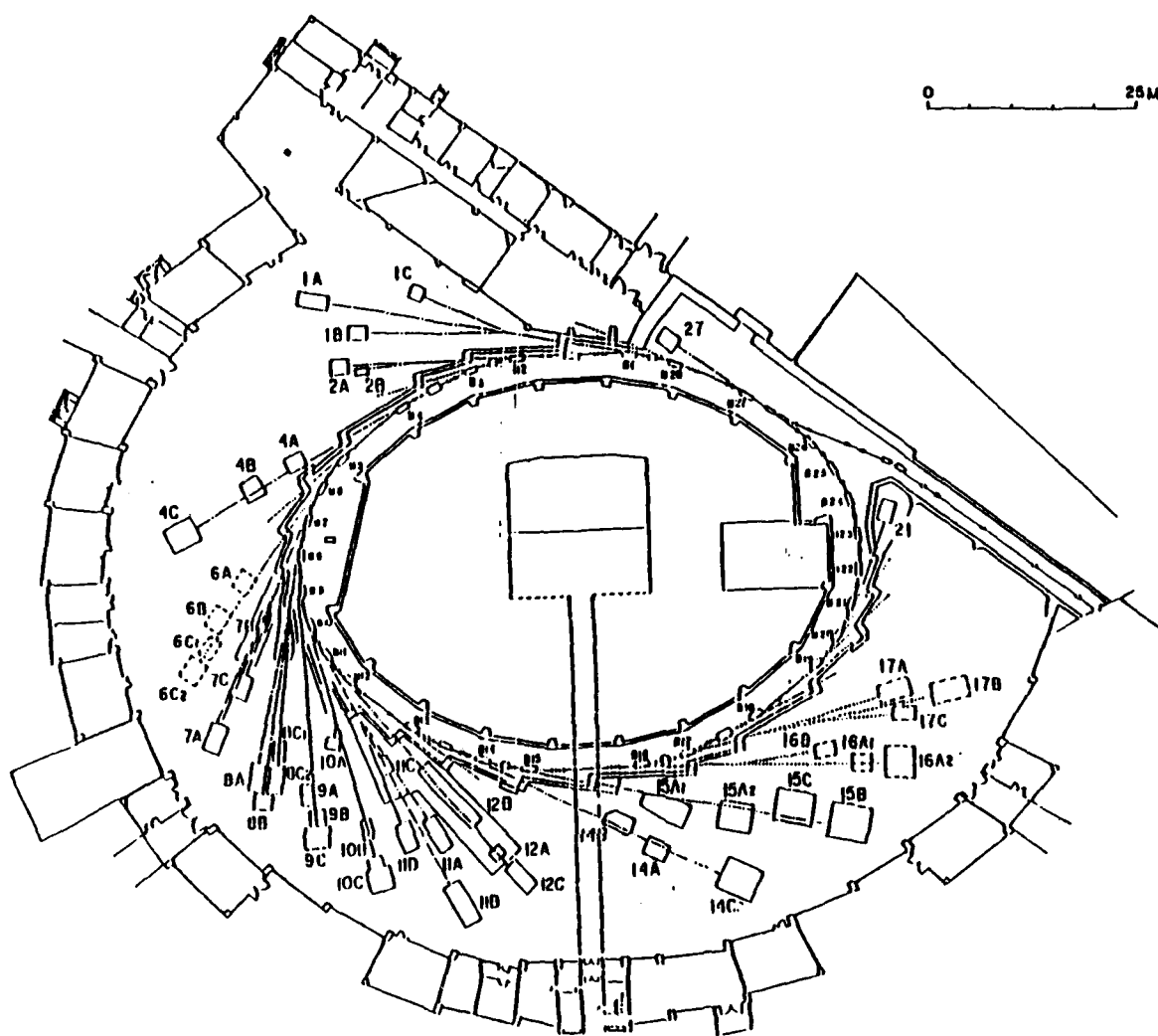


Figure 4. View of PF experimental hall in 1985.

(Taken from "Photon Factory," J. Tanaka, K. Huke, and J. Chikawa. Presented at the Workshop on Construction and Commissioning of Dedicated Synchrotron Radiation Facilities held at Brookhaven National Laboratory, October 1985.)

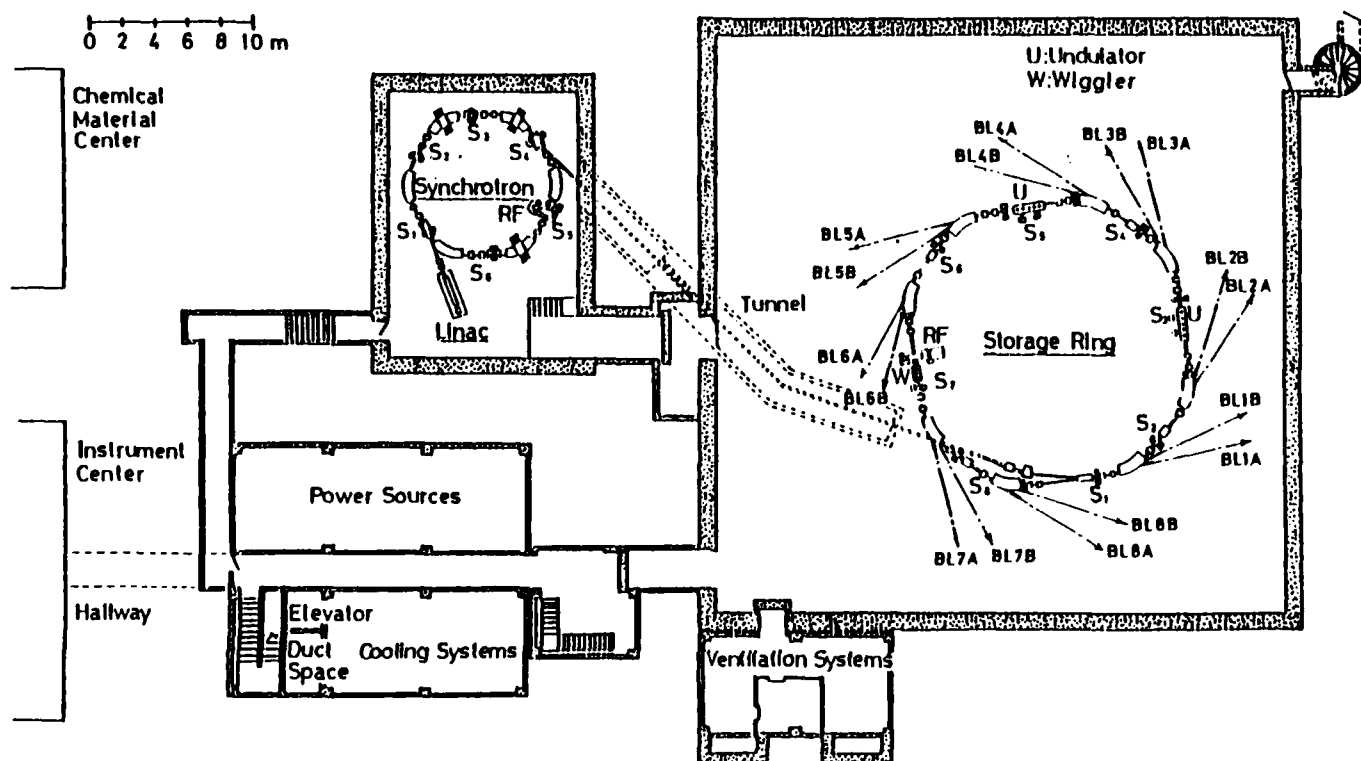


Figure 5. View of the basement of the UVSOR Facility.

(Taken from "Overview of the UVSOR Facility," T. Kasuga and M. Watanabe. Presented at the Workshop on Construction and Commissioning of Dedicated Synchrotron Radiation Facilities held at Brookhaven National Laboratory, October 1985.)

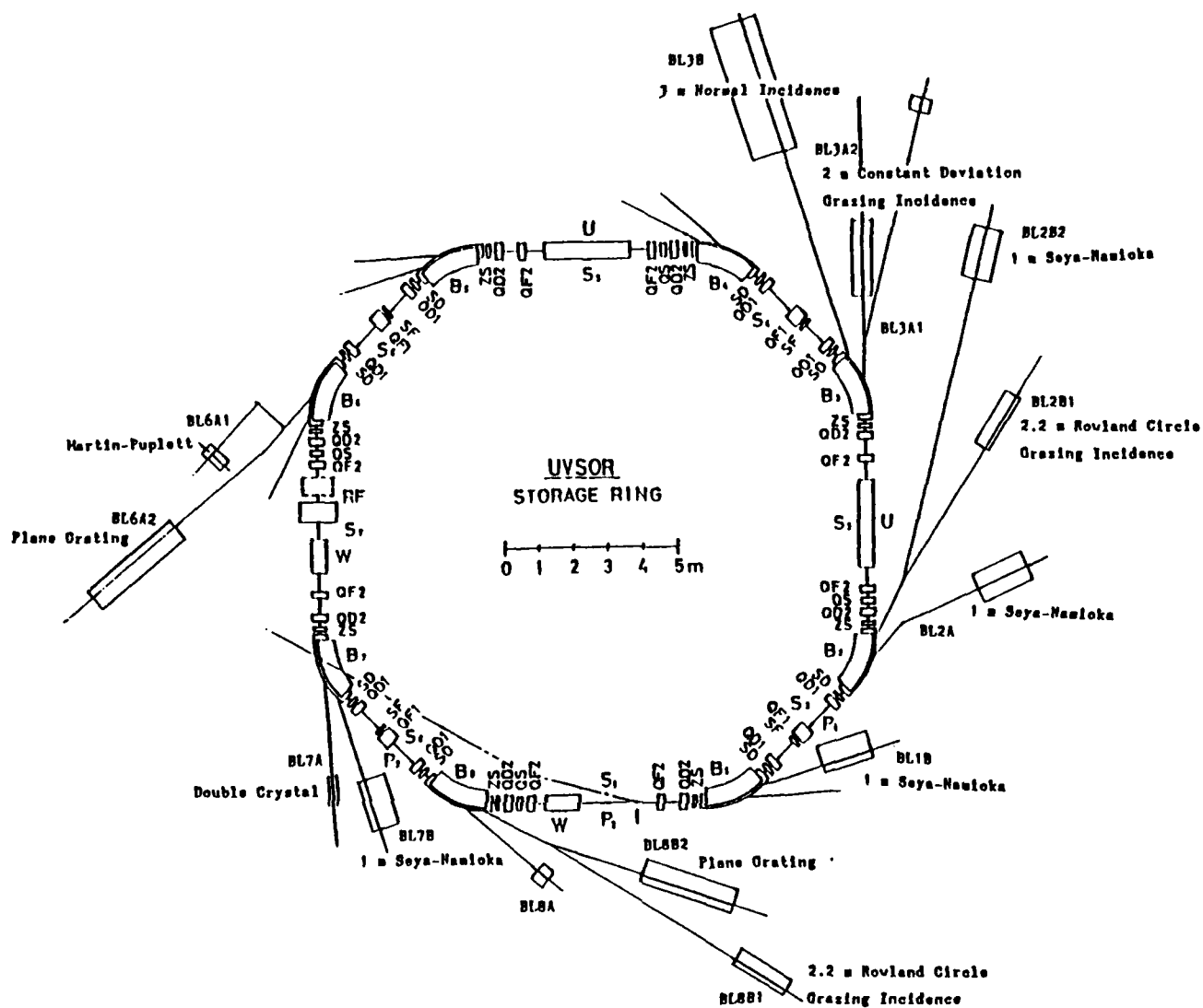


Figure 6. View of the UVSOR storage ring.

(Taken from "Overview of the UVSOR Facility," T. Kasuga and M. Watanabe. Presented at the Workshop on Construction and Commissioning of Dedicated Synchrotron Radiation Facilities held at Brookhaven National Laboratory, October 1985.)

TABLE I
STORAGE RING PARAMETERS^a

	16 segments	12 segments
Electron energy	E = 1 GeV	1 GeV
Circumference	$2\pi R$ = 182.4 m	141.6 m
Mean radius	R = 29.0 m	22.5 m
Revolution time	T = 608.4 ns	472.3 ns
Superperiodicity	8 or 16	6 or 12
Synchrotron radiation		
Energy loss per turn	U_O = 21.7 KeV	23.2 KeV
without insertion devices		
Critical energy (Bend magnets)	ϵ_C = 545 eV	581 eV
Number and length of straight section	16 x 5.3 m	12 x 5.3 m
Dipole magnets		
Magnetic field	B = 8.19 KG	8.73 KG
Bending radius	ρ = 4.074 m	3.820 m
Effective length	L_B = 1.6 m	2.0 m
Total number	16	12
Quadrupole magnets		
Strength	K = $<2.4 \text{ m}^{-2}$	$<2.3 \text{ m}^{-2}$
Gradient	g = $<8 \text{ T/m}$	$<7.7 \text{ T/m}$
Effective length	L_Q = 0.3 m	0.3 m
Number of families	2 or 4	2 or 4
Total number	64	48
Sextupole magnets		
Strength	$<0.75 \text{ m}^{-2}$	$<0.5 \text{ m}^{-2}$
Effective length	0.2 m	0.2 m
Number of families	2	2
Total number	64	48

^aTaken from "ISSP-KEK New Light Source Project," T. Ishii and G. Isoyama.
Technical Report of ISSP, Ser A, (1607) December 1985.

TABLE II
AN EXAMPLE OF OPERATION MODES^a

	16 segments	12 segments
Tunes	$\nu_x = 7.75$ $\nu_y = 4.75$	5.75 3.75
Momentum compaction factor	$\alpha = 3.81 \times 10^{-3}$	8.41×10^{-3}
Natural chromaticities	$\xi_x = -19.6$ $\xi_y = -9.0$	-11.3 -6.7
Damping times	$\tau_x = 57.6 \text{ ms}$ $\tau_y = 42.2 \text{ ms}$ $\tau_\epsilon = 27.7 \text{ ms}$	42.9 ms 40.8 ms 19.9 ms
Energy spread	$\sigma_\epsilon/E = 4.22 \times 10^{-4}$	4.34×10^{-4}
Emittance (zero coupling)	$\epsilon_x = 5.28 \text{ mm}^{\circ}\text{rad}$	13.5 mm ^o rad
Beam sizes and divergences at the center of straight section (full coupling)	$\sigma_x = 346 \text{ }\mu\text{m}$ $\sigma_y = 96 \text{ }\mu\text{m}$ $\sigma_{x'} = 12 \text{ }\mu\text{rad}$ $\sigma_{y'} = 28 \text{ }\mu\text{rad}$	505 μm 148 μm 21 μrad 45 μrad

TABLE III
TENTATIVE PARAMETERS CONCERNING RF ACCELERATION

	16 segments	12 segments
Frequency	$f = 105.19 \text{ MHz}$	101.62 MHz
Harmonic number	$h = 64$	48
Peak voltage	$v = 400 \text{ KV}$	411 KV
Momentum acceptance	$\Delta p/p = \pm 3.1\%$	$\pm 2.4\%$
Synchrotron frequency	$f_{\text{syn}} = 6.47 \text{ KHz}$	10.87 KHz
Synchrotron tune	$\nu_s = 3.94 \times 10^{-3}$	5.14×10^{-3}
Bunch length	$\sigma_l = 1.19 \text{ cm}$	1.60 cm
Touschek lifetime	$\tau_{\text{T}} = 4.1 \text{ }^{\circ}\text{A hrs}$	5.0 A ^o hrs

^aTaken from "ISSP-KEK New Light Source Project," T. Ishii and G. Isoyama.
Technical Report of ISSP, Ser A, (1607) December 1985.

TABLE IV
EXPERIMENTAL STATIONS OF THE PHOTON FACTORY^a

BL1 (NTT)	
1A	Semiconductor surface analysis
1B	X-ray lithography
1C	Photochemical reaction
BL2 (Undulator)	
2A	Soft x-ray experiment
2B	X-ray microscopy
BL4	
4A	Dispersive EXAFS, Trace element analysis
4B	Liquid/melt structure analysis
4C	Radiation effect on biocells X-ray diffuse scattering, fluorescent EXAFS (sagittally-focused double crystal)
BL6*	
6A	X-ray Weissenberg camera
6B	EXAFS (chemical cut crystal)
6C ₁	X-ray diffraction at low temperature
6C ₂	X-ray diffraction under high pressure and high temperature
BL7 (Tokyo University)	
7A	Soft X-ray photoemission spectroscopy (plane grating)
7B	Surface photochemical reaction (1 m Seya-Namioka)
7C	EXAFS and x-ray diffraction (sagittally-focused double crystal)
BL8 (Hitachi)	
8A	Soft X-ray spectroscopy (self-focusing plane grating)
8B	EXAFS (soft and hard x-ray double crystal)
8C ₁	X-ray lithography
8C ₂	X-ray tomography of minerals
BL9 (NEC)*	
9A	X-ray lithography
9B	Photochemical vapor deposition
9C	EXAFS and x-ray topography (sagittally-focused double) crystal)
BL10	
10A	Crystal structure analysis of minerals (4-circle goniometer)
10B	EXAFS (channel-cut monochromator)
10C	Small angle x-ray scattering of enzymes (focused double crystal)
BL11	
11A	Soft X-ray solid state spectroscopy (2 m Grasshopper)
11B	Surface EXAFS, soft x-ray standing wave (soft x-ray double crystal)
11C	VUV solid state spectroscopy (1 m Seya-Namioka)
11D	Angle-resolved photoemission spectroscopy (constant deviation)

^aTaken from "Photon Factory," J. Tanaka, K. Huke and J. Chikawa. Presented at the Workshop on Construction and Commissioning of Dedicated Synchrotron Radiation Facilities held at Brookhaven National Laboratory, October 1985.

BL12	12A	VUV gas spectroscopy (1 m Seya-Namioka)
	12B	VUV high resolution spectroscopy (6.6 m off-plane eagle mount)
	12C	Soft x-ray high resolution spectroscopy (10 m grazing incidence)
BL14 (Vertical wiggler)	14A	Crystal structure analysis of proteins (double crystal--4-circle goniometer)
	14B	High precision x-ray optics
	14C	High speed x-ray topography, X-ray radiograph (double crystal) X-ray magnetic scattering, Compton scattering
BL15	15A	Small angle x-ray scattering of muscles and alloys (focused bent crystal)
	15B	X-ray topography, X-ray interferometry
	15C	High resolution X-ray diffraction
BL16* (Multipole wiggler-undulator)	16A ₁ ,A ₂	Hard x-ray experiment (sagittally-focused double crystal)
	16B	VUV experiment (10 ~ 4000 eV)
BL17* (Fujitsu)	17A	X-ray lithography
	17B	EXAFS
	17C	Photochemical vapor deposition
BL21* (Light Source Division)		Beam monitoring and photodesorption experiment)
BL27* (Light Source Division)		Radiation test of mirrors

*Experimental stations under construction

TABLE V
SUMMARY OF X-RAY BEAM LINES AND OPTICS^a

Beam Line	Horizontal Acceptance Angle (mrad)	Typical Beam Spot Size (H mm x V mm)	Photon Flux at Sample Position	Monochromator (Crystal)	Energy resolution ($\Delta E/E$)	Energy range (KeV)	Mirror	Line Vacuum (Gas)
4A	6	50 x 5		none	white radiation	4 - 35	none	Vacuum
4B	4.5	50 x 5		none	white radiation	4 - 35	none	Vacuum
4C	4	50 x 5		double crystal Si (111) (sagittal focusing being prepared)	$\sim 2 \times 10^{-4}$	4 - 20	none	Vacuum
10A	1	10 x 3	1×10^9 at 10 KeV with flat Si (111)	Silicon (111) Germanium (111) Pyrolytic graphite (002) Curved Si (111) ($\alpha 8^\circ$)	5×10^{-3} $\sim 5 \times 10^{-4}$	6.5 ~ 25	none	Helium
10B	2	8 x 1	3×10^8 at 10 KeV with Si (311)	Channel-cut Si (311) Double Si (111) Double Si (220)	1×10^{-4}	6 ~ 30 3.5 ~ 15 5.5 ~ 25	none	Vacuum
10C	4	6 x 1.5	$\sim 10^{10}$ at ~ 8 KeV	double crystal Si (111) fixed beam position	2×10^{-4}	4 ~ 10	bent cylinder	Helium
14A	1.28	5 x 38		Double Si (111) Double Si (331) Double Si (551)	2×10^{-4}	5.1 ~ 19.1 12.9 ~ 48 21.1 ~ 78.6	Bent Cylinder for Vertical focusing, Pt-coated fused quartz	Vacuum (line) He (monochromator)
14B	2.2	5 x 30		Double Si (111) Double Si (220) Double Si (311)	2×10^{-4}	5.2 ~ 57	Sagittal focusing	Vacuum
14C	1.3	10 x 40		Double Si (111)	2×10^{-4}	5.5 ~ 43	none	Vacuum
15A	2	2.6 x 1.3	1×10^{10} at 8.3 KeV	Curved Si (111) ($\alpha=7.8^\circ$)	$\sim 10^{-2}$	5.6 ~ 12.4	Cylinder, fused quartz	Vacuum and He
15B	0.14	5 x 5	3×10^4 at 10.5 KeV	Channel cut fixed exit channel cut Double crystal	7×10^{-4} 7×10^{-4} 1.5×10^{-3}	10.0 - 34.0 3.5 - 16.0	none	Vacuum
15C	2	60 x 6	White			4 ~ 35	none	Vacuum

^aTaken from Photon Factory Activity Report, 1983/84.

TABLE VIa
SUMMARY OF VUV/SOFT X-RAY BEAM LINES AND OPTICS

BRANCH BEAM LINES	Monochromator	Grating (Crystal)	Groove density (l/mm)	Blaze (A)	Resolution	Wavelength range (A)
B1-A	Grating/Crystal Monochromator	Au-coated original InSb(111) Si(111)	2400		$E/\Delta E \sim 2000$	2 ~ 2000
B1-B	Filtered white					
B1-C	Filtered white					
B2-A	White/2m grazing incidence (85°)	Hitachi Au-coated replica	2400	30	$\Delta\lambda=0.02$ A for 10 μ -10 μ silica	30 ~ 200
B2-B	Channel-cut double crystal	Beryl(10 $\bar{1}$ 0) InSb(111)	2d-15.9 A 2d-7.4806 A			8 ~ 16 3 ~ 8
B11-A (2GH)	Grasshopper Mark VII 2m grazing incidence Fixed incidence angle of 88°	Hitachi Au-coated replica (pyrex)	2400 1200	16.6 33.3	$\Delta\lambda=0.02$ A $\Delta\lambda=0.04$ A for 10 μ -10 μ silica	10 ~ 145 10 ~ 290
B11-B (DXH)	Jumbo Jr. Double crystal monochromator	Ce(111) InSb(111) Beryl(10 $\bar{1}$ 0)	2d-6.53 A 2d-7.4806 A 2d-15.9 A		$\Delta E=1eV$ at 2KeV $\Delta E=0.8eV$ at 2KeV $\Delta E=0.6eV$ at 1KeV	2.7 ~ 6.2 3 ~ 7 8 ~ 16
B11-C (SSH)	Im Seya-Hamioka Constant deviation of 70°	B & L Au-coated replica	2400 1200	694 1300	$\lambda/\Delta\lambda=2000$ ~ 3000	400 ~ 1700 400 ~ 3500
B11-D (CDH)	2m-grazing incidence constant deviation monochromator $\alpha + \beta = 154^\circ$	B & L Au-coated replica	2400 1200 600	32 116 460	$\lambda/\Delta\lambda \sim 1700$ for 25 μ -25 μ silica	80 ~ 150 120 ~ 300 240 ~ 600
B12-A (GSH)	Im Seya-Hamioka Constant deviation of 70°	B & L Au-coated replica	2400 1200	508 536	$\Delta\lambda=0.4$ A at 500 A for 100 μ -100 μ silica	350 ~ 1000 350 ~ 2000
B12-B (6VOPE)	6.65m normal incidence off-plane Eagle mounting	B & L Au-coated replica	1200 1200	1500 5500	$\Delta\lambda=0.003$ A at 500 A for 11th order	400 ~ 2500
B12-C (10G1H)	10m grazing incidence Fixed incidence angle of 89°	Hitachi Au-coated replica (pyrex)	2400 1200	9.5 10.9	$\Delta\lambda=0.002$ A $\Delta\lambda=0.004$ A for 5 μ -5 μ silica	6 ~ 25 6 ~ 50

TABLE VIb
SUMMARY OF VUV/SOFT X-RAY BEAM LINES AND OPTICS

BRANCH BEAM LINES	PRE - MIBRONS						Horizontal & Vertical acceptance (mrad)
	Type	Radius of curvature (mm)	Angle of incidence	Material	Coating Material	Dimensions (mm)	
B1-A	Parabol- oidal		89°	Fused Quartz			4.0 ^h =1.0 ^v
B1-B	Plane		88° ~ 89°	SIC			1.2 ^h =4.0 ^v
B1-C	Toroidal		86°	Fused Quartz	Pt		2.0 ^h =4.0 ^v
B2-A	Plane	—	88°	SIC	Pt	120 ^l =60 ^v =15 ^t	—
B2-B	—	—	—	—	—	—	—
B11-A (2CH)	Spherical	360000	88°	Fused Quartz	Pt	400 ^l =170 ^v =40 ^t	1.3 ^h =0.4 ^v
	Spherical	28000	88°	Fused Quartz	Au	300 ^l	
B11-B (DSH)	Bending Cylinder	p=300 R~950000	89°	Fused Quartz	Pt	580 ^l =140 ^v =30 ^t	4.0 ^h =0.6 ^v
B11-C (SSN)	Plane	—	77.5°	SIC	none	250 ^l =100 ^v =40 ^t	4.8 ^h =3.0 ^v
	Concave	3600	42.5°	Fused Quartz	Pt	100 ^l =100 ^v =20 ^t	
B11-D (CDH)	Cylindrical	p~750	86°	SIC	Pt	400 ^l =60 ^v =40 ^t	2.0 ^h =2.0 ^v
	Plane	—	86°	Fused Quartz	Au	50 ^l =40 ^v =10 ^t	
	Concave	4000	86°	BK-7	Au	50 ^l =40 ^v =10 ^t	
B12-A (CSN)	Plane	—	80°	SIC	none	250 ^l =700 ^v =40 ^t	2.4 ^h =1.5 ^v
	Concave	6250	45°	Fused Quartz	Pt	100 ^l =20 ^t	
B12-B (6VOPE)	Plane	—	80°	SIC	none	280 ^l =100 ^v =40 ^t	5.0 ^h =3.6 ^v
	Concave*	4321	35°	Pyrex	Pt	110 ^l =20 ^t	
	Concave*	2188.5	45°	Pyrex	Pt	110 ^l =20 ^t	
B12-C (10G1H)	Plane	—	86.85° ~ 88.83°	SIC	Pt	120 ^l =60 ^v =15 ^t	0.14 ^h =0.4 ^v
	Concave	8903	89°	Pyrex	Pt	90 ^l =15 ^t	
	Concave	7527	89°	Pyrex	Pt	90 ^l =15 ^t	

TABLE VIc

SUMMARY OF VUV/SOFT X-RAY BEAM LINES AND OPTICS

BRANCH BEAM LINES	REFOCUSING MIRRORS						
	Type	Radius of curvature (mm)	Angle of incidence	Material	Coating Material	Dimensions (mm)	Beam Size (mm)
B1-A	Parabol- oidal		89°	Fused Quartz			
B1-B						19 mm ϕ	
B1-C						2 ^h =10 ^v	
B2-A							
B2-B							
B11-A (2CH)	Bent Cylinder	R~1000	89°	Pyrex	Pt	220 ^l =24 ^v =6 ^t	8 ^h =0.3 ^v
B11-B (DXH)							8 ^h =1 ^v
B11-C (SSH)	Toroidal	p=2000 R=125	72.5°	Pyrex	Au	90 ^l =50 ^v =10 ^t	~1 ϕ
B11-D (CDM)	Toroidal	p=400 R=3100	77°	BK-7	Au	60 ^l =40 ^v =10 ^t	0.5 ^h =0.5 ^v
B12-A (CSH)	Plane	—	80°	Pyrex	Pt	40 ^l =40 ^v =10 ^t	~1 ϕ
	Toroidal	p=340 R=2000	70°	Pyrex	Pt	40 ^l =40 ^v =10 ^t	
	Plane	—	80°	Pyrex	Pt	40 ^l =40 ^v =10 ^t	
B12-B (6VOPE)							
B12-C (10GIM)							

TABLE VII
MONOCHROMATORS AT UVSOR^a

Beam Line	Monochromator, Spectrometer	Wavelength Region	Acceptance Angle(mrad)		Experiment
			Horiz.	Vert.	
BL1B*	1 m Seya-Namioka	2000-300 Å	60	6	Gas
BL2A	1 m Seya-Namioka	4000-300 Å	40	6	Gas
BL2B1*	2.2 m Rowland Circle Grazing Incidence	220-20 Å	10	2	Gas
BL2B2	1 m Seya-Namioka	2000-300 Å	20	6	Gas
BL3A1*	None (Filter, Mirror)		(U) 0.3	0.3	Gas & Solid
BL3A2*	2 m Constant Deviation Grazing Incidence	1000-100 Å	10 (U) 0.3	4 0.3	Gas & Solid
BL3B	3 m Normal Incidence	4000-300 Å	20	6	Gas
BL6A1*	Martin-Puplett	5 mm-50 μm	80	60	Solid
BL6A2	Plane Grating	6500-80 Å	10	6	Solid
BL7A	Double Crystal	15-8 Å	2	0.3	Solid
		15-2 Å	(W) 1	0.15	
BL7B	1 m Seya-Namioka	6500-300 Å	50	6	Solid
BL8A	None		25	8	Irradiation, User's Instrum.
BL8B1*	2.2 m Rowland Circle Grazing Incidence	220-20 Å	10	2	Solid
BL8B2	Plane Grating	6500-80 Å	10	6	Solid

* : under construction. U : with an undulator. W : with a wiggler.

^aTaken from "Overview of the UVSOR Facility," T. Kosuga and M. Watanabe. Presented at the Workshop on Construction and Commissioning of Dedicated Synchrotron Radiation Facilities held at Brookhaven National Laboratories, October 1985.

HIGH PRECISION FREQUENCY STANDARDS IN JAPAN

Alfred Kahan

INTRODUCTION

Visits to several Japanese universities and industrial organizations active in research and development of piezoelectric materials, bulk wave resonators, crystal oscillators, and atomic time standards and frequency control devices are discussed in this article. Owing to time limitations, I specifically excluded visits to companies developing surface acoustic wave (SAW) devices and semiconductor optical diodes.

GENERAL CONCLUSIONS

Industrial development of high precision time and frequency control devices in Japan lags several years behind the United States. The market for high precision frequency standards is limited, and the Japanese concentrate on improving, mass producing, and lowering costs of low precision temperature compensated crystal oscillators (TCXOs). They emphasize reliability, size reduction, and integration of modern electronics and LSI processing technology. Technical ideas for high precision devices are taken from U.S. publications. For example; the SC-cut crystal resonator, under active U.S.-development for the last ten years, is just starting to be pursued in Japan.

Cost is the most important performance parameter for mass produced TCXOs. In addition to modern fabrication technologies, costs are also reduced by fabricating devices in low labor cost countries. Some Japanese companies have established subsidiary affiliates in Southeast Asia, specifically in Malaysia. Labor intensive crystal lumbering, blank shaping, polishing, and low-technology fabrication processes are performed in Malaysia, and semifinished products are returned to Japan for high technology processing and final assembly.

Japanese universities conduct extensive theoretical and experimental research on piezoelectric materials, resonators, oscillators, and atomic standards. The number of academic institutions and investigators in this research exceeds, both comparatively and quantitatively, the corresponding numbers in the U.S. Research quality is excellent. I am unaware of any time and frequency standards research support by the Japanese Self-defense Forces. There is a conscious effort to separate universities from defense-related research. Most universities are either national or prefectural-government funded, and research funds are provided as an integral part of the budget. Additional research funds can be obtained from grants given by the Ministry of Education, Science and Culture. University researchers do occasionally interact with, and are funded by, industry. The basic situation is one of advanced research and development at the university level, but the results are not transferred in a systematic manner to industry.

One research effort pursued in the U.S. is the development of a laser diode pumped cesium or rubidium beam stabilized frequency standards. The feasibility of such devices were verified experimentally. The potential payoff of an optically pumped cesium device far outweighs the benefits predicted for the rubidium unit, and current U.S. programs emphasize the cesium device. The laser pumped unit will improve significantly the accuracy and short-term stability, and at the same time reduce life cycle cost. RADC supported the National Bureau of Standards (NBS) in this research, and RADC is currently funding an industry contract for a prototype model. A major problem for this program is

the unavailability of a reliable supply of stable, single-mode laser diodes with high intensity output at the optical cesium transition wavelength, 852 ± 5 nm. Most laser diodes are developed and fabricated in Japan, with major suppliers being Hitachi, Mitsubishi, and NEC. The driving force for laser diodes is the commercial entertainment industry. It happens that the rubidium optical transition used for optical pumping is within the acceptable wavelength range of diodes used for laser and audio discs. The cesium transition is outside the commercially acceptable wavelength range, and the manufacturers are unwilling to institute testing procedures for high intensity diodes peaking at the cesium transition. Hitachi has supplied cesium wavelength diodes, at the very high price of \$250 per diode, but even at these prices they are reluctant to wavelength sort their lasers on a regular basis.

Japanese university researchers are also engaged in optical pumping experiments. I had several discussions with Japanese investigators concerning the availability of laser diodes. I suggested that they persuade the manufacturers to sell the entire batch of long wavelength rejects, and that the universities perform the selection. This operation would be cheaper than the companies performing the selection. I was told that Mitsubishi is more willing to be cooperative on a scientific and development level than Hitachi.

The principal Japanese industrial organizations active in bulk wave piezoelectric device development include Fujitsu Limited, Kinseki, Ltd., Kokusai Denshin Denwa (KDD), Nihon Dempa Kogyo (NDK), Nippon Electric Corporation (NEC), Nippon Telegraph and Telephone Corporation (NTT), Suwa Seiko, Tokyo Dempa, and Toyo Communications Equipment (Toyocom). Atomic standards are developed by Fujitsu, NEC, and NTT.

During this visit, as I was able to call on companies such as Fujitsu, NDK, NTT, and Toyocom. I also visited the Radio Research Laboratory, Tokyo Institute of Technology (both campuses), Yamanashi University, and the Tokyo Metropolitan University. Based on my findings and discussions, I recommend that we establish contact with and schedule visits to the Fujitsu production plant in Oyama, KDD, Kinseki, NEC, Seiko, the Toyocom production facility at Miyazaki, the National Space Development Agency of Japan (NASDA), Nagoya University, the National Research Laboratory of Metrology, Shinshu University, Yokohama National University, and the companies active in the fabrication of laser diodes.

In the following pages I will summarize my impressions of the visits to the particular organizations.

RADIO RESEARCH LABORATORY (RRL)

Ministry of Posts and Telecommunications
2-1 Nukui-Kitamachi, 4-chome, Koganei-shi, Tokyo

Principal point of contact:

Mr. Koji Nakagiri, chief, Atomic Standards Section

Others: Dr. N. Wakai, director general, RRL

Mr. H. Okomoto, director, Standards and Measurements Division

Dr. Y. Yoshimura, chief, Frequency and Time Measurements Section

RRL is a government research institute attached to the Ministry of Posts and Communications. It employs 450 people, with research activities in integrated

communication systems, space communications, space and atmospheric sciences, remote sensing, and frequency standards. Services provided include ionospheric data, prediction and disturbance warning of ionospheric propagation conditions, radio equipment test and calibration services, and dissemination of time signals and standards frequencies. It also operates several radio wave observatories. It is the Japanese counterpart of NBS in Boulder, Colorado.

I visited the Standards and Measurement Division (Mr. H. Okotomo, director). The division is structured into five sections:

- Atomic Standards (Mr. K. Nakagiri),
- Frequency and Time Measurements (Mr. Y. Yoshimura),
- Radio Measurements (Mr. T. Kawana),
- Frequency and Time Standards (Mr. S. Kobayashi), and
- Calibration Approval (Mr. S. Watanabe).

The division is responsible for determining and maintaining national standards of frequency as well as Japan Standard Time (JST). They operate and maintain a collection of cesium atomic clocks. Research is pursued for higher accuracy standards, advanced cesium clocks, hydrogen masers, and superconducting cavity stabilized oscillators.

RRL operates three space links for time transfer--the domestic, the Asian, and the U.S.-European link. RRL conducts domestic time transfer experiments between RRL headquarters, Kashima Space Center, and the International Latitude Observatory at Mizusawa. Time transfer comparisons techniques include the U.S. space deployed general positioning system (GPS), signal transmission via satellite, and very long baseline interferometry (VLBI). RRL has developed a GPS receiver for routine time comparisons with the U.S. Naval Observatory (USNO) to a precision of 10-20 ns. RRL also developed a time transfer receiver for the Japanese geostationary meteorological satellite (GMS), which is used for time transfer within Asia. GMS time transfer experiments will include Australia, the Shanghai Observatory of China, and the Korean Standard Research Institute. Details of this work are reviewed in the Proceedings of the *IEEE* issue on *Radio Measurement Methods and Standards*, K. Yoshimura, *et al.*, "Research Activities on Time and Frequency Transfer Using Space Links," *Proc. IEEE*, 74, 157 (1986).

The RRL primary cesium beam frequency standard accuracy was improved to 1.1×10^{-13} . The 6 cm beam focus magnet was replaced by a 3 cm one and the cesium beam velocity was decreased. The device also incorporates a hexapole magnet, developed for hydrogen maser investigations.

RRL developed field operable active hydrogen masers for time comparisons with USNO to an accuracy of 10 ns. These masers are cavity auto tuned, and at an averaging time of a few hundred seconds have a frequency stability of 2×10^{-15} . Seven masers were built. Two of the masers are deployed at the Kashima Space Center VLBI site and are used in a joint U.S. (NASA)-Japan experiment on earthquake prediction. Earth crustal plate movements are measured to a precision better than 3 cm. In one year, between 1984 and 1985, the distance between U.S. and Japan, and between continental U.S. and Hawaii, remained unchanged, but the distance between Japan and Hawaii changed by 4 cm.

RRL also pursues research on optically pumped cesium beam standards. A cesium filled Rabi cavity was optically-pumped and microwave resonance lines were observed. The single-mode Hitachi HLP 1400 diode, wavelength selected at 852 ± 5 nm, is

temperature controlled to 1 millidegree, and has a linewidth of 60 MHz. Mr. Munakata, Hitachi Semiconductor Division, is the contact point for these diodes. RRL is preparing an experiment using a 40-cm-long Ramsey cavity. RRL is also conducting experiments on ion storage frequency standards. I find that this work lags considerably behind U.S. NBS investigations.

RRL is developing a superconducting cavity stabilized oscillator. A Gunn diode oscillator is stabilized by a 9.2 GHz niobium superconducting cavity, and the cavity itself is used as a frequency determining element in the frequency discriminator circuitry. Frequency stability at a 500 s sampling time is 1.4×10^{-14} . Details of this work are given in B. Komiyama, "A 9.2 GHz Superconducting Cavity Stabilized Oscillator," *Proc. 39th Annual Symposium Frequency Control (ASFC)*, 159 (1985). In order to decrease the vibration sensitivity of the device, the next phase will experiment with a high-Q lead-on-sapphire cavity.

The Division maintains JST by an assemble of eight Hewlett-Packard 5061A cesium clocks. The HP units are old but are performing very well. Lifetimes of high performance tubes are three-four years, and standard tubes last five-six years. Some tube lifetimes exceed ten years, and are still going strong. Currently, RRL is replacing the Toshiba computer coordinating the cesium clock assemble with a HP 2622A. They find HP equipment superior. Timekeeping was a labor intensive operation, but automating this function resulted in a significant reduction in staff.

A second Japanese government organization, National Research Laboratory for Metrology (NRLM), is also active in developing cesium beam standards. NRLM is attached to another ministry, and there is some duplication in functions and research. I did not visit NRLM. NRLM programs and results are reviewed by Y. Nakadan and Y. Koga, "Recent Progress in Cs Beam Frequency Standards at the NRLM", *IEEE Trans. Instrum. and Meas.* IM-34, 133 (1985).

RRL trains Asian and Third World personnel in timekeeping and time and frequency maintenance technology. Currently there are two Pakistani scientist at RRL, and they will implement the Pakistani Time Standards Laboratory. They are trained for several months, with all expenses paid for by the Japanese government.

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Principal points of contact:
Dr. Nobunori Oura
Dr. Motoichi Ohtsu
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Others: Dr. Naimu Kuramochi
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Dr. Shigeyuki Somiya

Tokyo Institute of Technology, is the leading, and largest, technical institute in Japan. TIT enrollment is 5300 students (3400 undergraduates in science and engineering, 1500 in the master's programs, and 400 in doctoral programs). TIT has a faculty of 450 professors and 430 associates. In 1984, TIT conferred 800 bachelor, 700 master, and 200 doctoral degrees. The annual budget is \$100 million, and it also receives \$6 million in grants for scientific research from the Ministry of Education, Science and Culture. There are approximately 350 foreign students, including 100 from the People's Republic of China, 100 from Korea, 40 from Taiwan, and four from the U.S. The undergraduate school is located at the Ookayama campus in Tokyo. Also located at the Tokyo campus is the graduate Department of Nuclear Engineering, the Research Laboratory of Nuclear Reactors, and the International Cooperation Center for Science and Technology. The other graduate school departments, and the Research Laboratories of Resource Utilization, Precision Machinery and Electronics, and Engineering Materials are situated at the Nagatsuta campus in Yokohama.

I visited both campuses, Professors Oura and Ohtsu at Yokohama and Professor Shimizu in Tokyo.

- Professor Oura. Investigations carried out by Oura and his associate N. Kuramochi include:

- . Development of highly stable crystal resonators for atomic frequency standards.

The short-term frequency stability of an atomic frequency standard, such as a cesium beam or a rubidium gas cell device, is determined by the crystal oscillator frequency stability. Oscillator stability is largely determined by the crystal resonator. Oura is studying frequency stability as a function of environmental temperature, forces applied externally to the resonator, and variations with the crystallographic angles of the quartz resonator disks.

- . Thermal behavior of resonators.

High precision oscillators incorporate stable resonators using either AT- or SC-cut quartz. When the environmental temperature around the resonator changes, the observed frequency offset is considerably larger than estimated from static frequency-temperature characteristics. This "thermal shock" phenomenon is attributed to thermal stress caused by ununiform temperature distribution in the quartz plate. Oura is experimenting with different electrode configurations to improve the thermal balance and to reduce the thermal stress of the crystal resonators. A He-Ne laser beam is used to irradiate, and heat, different portions of the principal crystal surfaces, and corresponding frequency shifts are measured. Oura finds that in an AT-cut plate, there are three in-plane regions which show drastic differences in frequency offset for the same irradiating power. Also, frequency offset of a SC-cut plate, for the same irradiating laser power, is ten times smaller than for the corresponding AT-cut crystal.

- . Support structure for quartz crystal plates.

In a resonator, the circular quartz plate is usually supported on its periphery with two, three, or four metal ribbons. Long-term stability, or aging, is attributed partially to crystal impurity effects and partially to stress relief caused by deformation and thermal expansion of the supports. Oura is studying resonator stability as a function of applied external force, angle of cut, and mechanical support structure. The inverse phenomena,

maximum frequency sensitivity to external force, suggests using the resonator device as a force sensor. Oura is pursuing the design of such a transducer.

- . Frequency sensitivity of quartz resonators in an acceleration field.

One of the major problems faced in deploying an oscillator on a moving platform is oscillator frequency sensitivity to an acceleration field. TIT constructed a centrifugal accelerator capable of generating 60 G. Oura is using this device and measures the force-frequency characteristics of 5 MHz, fifth overtone, AT- and IT-cut plates as a function of crystal supports and crystallographic azimuth angle orientation with respect to the supports. The data is correlated and evaluated based on force-frequency coefficients, derived from a theoretical analysis of the problem.

- . Frequency stability and miniaturization of rubidium frequency standards.

Rubidium frequency standards are being miniaturized by using a small composite-type light source. The light source is composed of a cylindrical Rb-87 lamp, 10 mm diameter, and a Rb-85 filter cell 3-7 mm long attached to the front flat face of the lamp. This composite device is operated in an oven at about 100°C. The light source is 4 cm long and has a 3 cm diameter. Oura and his coworkers are studying light shift effects, and the ultimate frequency stability of this type of a standard.

- . Laser diode pumping of rubidium frequency standards.

GaAlAs laser diodes, at 0.78 μ m wavelength, are used extensively in commercial video and audio disk systems. This wavelength coincides with the Rb-D₂ transition line, and these diodes can be used as light sources, instead of the usual high frequency discharge Rb lamp. Owing to the strong light intensity, a laser diode source may improve the short-term stability of the Rb gas cell. Oura is constructing a physics package incorporating the laser diode pumping scheme.

- Professor Somiya.

I paid a courtesy call on Professor Somiya, the director of the Laboratory for Advanced Ceramics. He specializes in hydrothermal growth of ceramics. He has a large laboratory with extensive high temperature and high pressure apparatus for growing and synthesizing materials by the hydrothermal technique. Currently he is working on high temperature ceramics for automobile engines. He is the chairman of the International Conference on Hydrothermal Growth. Dr. Armington, RADC/ESM, visited him previously. Similarly, Professor Somiya visited RADC in December 1985. He has large-sized samples of iron and titanium doped quartz (amethyst), which he obtained from the U.S.S.R. The Russians grow these crystals for gem applications. He claims, and I agree with him, that for gem applications the crystals are of poor quality, and that the amethyst grown by NDK (Japan) is superior in appearance.

- Professor Ohtsu.

Professor Ohtsu, whom I also visited, is an internationally recognized researcher in lasers, specifically semiconductor diodes. One of his programs is laser diode excitation of optically pumped frequency standards. This work is independent of the previously mentioned investigations of Oura. The following paragraphs outline some of the research efforts conducted by Ohtsu.

. Temporal coherence of semiconductor lasers.

Ohtsu proposed that electrical feedback will improve laser coherence. Results using this technique were recently published and will not be discussed here. M. Ohtsu and S. Kotajima, "Linewidth Reduction of a Semiconductor Laser by Electrical Feedback," *IEEE J. Quantum Electron* QE-21, 1905 (1985). Since this article was published, the laser linewidth has been further reduced, from 330 kHz to 200 kHz, by improving the feedback loop and reducing detector noise. Ohtsu is giving an invited talk on this topic, "Demonstration and Application of Frequency Stabilization and Linewidth Reduction in Semiconductor Lasers" at the forthcoming IQEC '86. Currently he is investigating two specific applications of the coherent laser:

- A ring Fabry-Perot resonator-type fiber gyro to measure fluctuations in the rotational speed of the earth; that is, detecting the anomalous Chandler wobble. The purpose of this measurement is earthquake prediction. This experiment uses a KDD fabricated 1.5 μ distributed feedback laser, linewidth narrowed to 250 kHz, and a 1.5 km fiber optic cable. The sensitivity of this measurement will be improved by replacing the current cable with a 20 km long fiber.
- Laser diode pumped rubidium frequency standards. In a rubidium standard, the 0.781 nm ^{87}Rb double resonance spectral line is used as a frequency reference for microwave frequency stabilization. Previously, systematic experimental studies using laser diode pumping sources were limited due to insufficient laser reliability. Using the coherent laser Ohtsu obtains, even without optimizing servocontrol parameters, a stability of $9.4 \times 10^{-12} (\tau)^{-0.5}$ at a rubidium vapor temperature of 48°C.

Ohtsu is also able to reduce laser linewidth by using the ^{87}Rb both as the sample and as a phase modulator for the laser light wave. He is using the resultant FM sidebands as modulators, and he obtains an ultranarrow 20 Hz double resonance linewidth. Details of this experiment were submitted to the IQEC '86. (The Rb phase modulated laser technique is also employed by Mark Levinson, IBM, San Jose, California, and John Hall, Xerox.) For these experiments, Ohtsu uses the Hitachi HL 7802E laser, 10 mW output at rubidium transition wavelength. This laser has excellent thermal characteristics, a critical factor for high power pumping. At the current rate of exchange, the cost of this diode is approximately \$175. The same type of laser diode pumping experiments can also be performed at the 0.852 nm cesium transition wavelength. Ohtsu is well aware of the advantages of laser pumping cesium, but currently he is limiting his investigations to rubidium due to the difficulties in obtaining good diodes at the cesium wavelength. Mitsubishi also supplies laser diodes.

. Mode-hopping phenomenon in AlGaAs lasers.

When the laser is operated in a multilongitudinal mode high level fluctuations are induced in the low Fourier frequency range. This phenomenon has been attributed to mode hopping. Ohtsu measured these fluctuations precisely, and performed analog computer simulation of this phenomenon based on the Fokker-Planck equations. Results of these investigations were just published, M. Ohtsu, Y. Teramachi, Y. Otsuka, and A. Osaki, "Analyses of Mode-hopping Phenomena in an AlGaAs Laser," *IEEE J. Quantum Electron* QE-22, 535 (1986), and will not be discussed.

Ohtsu's laboratories are scattered over four buildings and are very well equipped. His

equipment also includes a 50-m-long He-Ne laser interferometer housed in an optical tunnel. This is used to measure earth vibrations, and it detects volcanic eruptions and "strong" earthquakes.

- Professor Shimizu.

Shimizu is known primarily for work in SAW-related devices. Even though this trip excluded visits to organizations specializing in SAW-type devices, I wanted to discuss with Shimizu his current investigations on leaky SAWs, a mixture of surface and bulk wave propagation. The most widely applied SAW device uses ST-cut quartz, a 42.75° rotated Y-cut with the acoustic waves propagating along the x-axis, which has a zero temperature coefficient at room temperature. At the Ultrasonics Symposium in 1985, Shimizu described a new quartz orientation, which has an extremely high temperature stability between -20 and $+80^\circ\text{C}$. For this cut, the surface propagation is not an ordinary Rayleigh wave but a leaky surface wave; that is, it radiates some bulk wave energy into the substrate. He designates this device as "leaky surface wave." At 180 MHz, he obtains a Q of 22,000. At the present time, the highest frequency leaky surface device they fabricated is a $0.23\ \mu$ interdigital gap unit with $f = 4.29\ \text{GHz}$. These devices were fabricated by NEC. According to Shimizu, these devices have many advantages over standard SAW devices. NEC is very excited about this development and claims that leaky SAWs may replace SAW units in narrowband filter applications. The major limitation of the leaky SAW device is the small electromechanical coupling coefficient. For TV or telerecorder applications, one needs a larger coupling coefficient. Shimizu showed me unpublished calculation for lithium tantalate and lithium niobate leaky SAWs. For each of the lithium compounds, he also finds an angular orientation which is relatively temperature insensitive between -20 and $+80^\circ\text{C}$, and at the same time has a very high coupling coefficient, k^2 approximately 15%. The coupling coefficient of the comparable SAW device is 4.8%. NEC is fabricating the experimental lithium compound devices. If Shimizu's calculations are confirmed experimentally, it will constitute a major advance in acoustical devices.

TOYOCOM

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Toyocom manufactures analog and digital transmission system equipment, subscriber carrier terminals and modems, mobile radio equipment, paging receivers and cellular telephones, and time code generators and terminals for satellite communication systems. (The principal customers of these devices are NTT and KDD.) Toyocom also fabricates office computers, automatic ticket vending machines, and bill-coin changers incorporating state-of-the-art "mechatronic" technology. In defense electronics, Toyocom produces airborne transponders, IFF equipment, and multiplex data transmission radios. Toyocom fabricates a full line of quartz and crystal-based electronic components. Toyocom employs 1500 people, but the number of employees including subsidiaries exceed 2500.

Organizationally, Toyocom is structured into six divisions, research and development, communication systems, electronic equipment, radio applications, mobile radio, and crystals.

The crystal division products include quartz, resonators, quartz and monolithic crystal filters, oscillators, SAW devices, and quartz optical components. Toyocom was the first Japanese industrial company to grow cultured quartz. In 1975, they established a subsidiary in West Germany, Toyocom Quartz GmbH, which became one of the principal producers of cultured quartz in Europe. There are four Toyocom facilities in quartz growth and crystal-based electronics. The Sagami Plant prototype facility in Samukawa-machi, Koza-gun, Kanagawa prefecture; the quartz production facility and manufacturing site for higher quality oscillators and filters at the Hobara Factory in Hobara-machi, Date-gun, Fukushima prefecture; the crystal resonator and lower quality oscillator fabrication facility at the Odaka Factory in Odaka-machi, Souma-gun, Fukushima prefecture; and the new quartz production growth and optical blank processing facility being installed at the Miyazaki Works in Kiyotake-cho, Miyazaki-gun, Miyazaki prefecture. K. Nagai, the design engineer of this new facility, will become its manager. I visited the Sagami Plant, situated near greater Tokyo.

At the Sagami Plant there are autoclaves which are rated at 300 liters, 30 cm (12") inside diameter by 5 m (16.5'), and produce 150 kg (330 lb) of quartz per autoclave run. The high pressure growth is in a NaOH solution, at a growth rate of 0.5 mm per day.

The Hobara Factory has a much higher production capability. Autoclaves are rated at 1000 liters, 40 cm inside diameter by 8 m. At Miyazaki, they installed eight enormous autoclaves, each rated at 5000 liters, 65 cm inside diameter by 15 m (25.6" by 50'), each producing 2.5 tons of quartz per autoclave run. All growth is done with the NaOH process at a pressure of 1300 kg/cm² (1250 atm). Toyocom personnel invited us to visit the other production facilities at a future date.

R&D at Sagami is limited to growing berlinite. Toyocom is satisfied with current quartz quality, except problems related to inclusions, specifically tuhualite, a sodium-iron-silicate compound. Toyocom is basically a production facility for low- and intermediate-grade quartz and they concentrate their efforts on improving large-scale autoclave production runs. Toyocom characterization facilities include low temperature infrared spectroscopy and x-ray diffraction equipment.

Toyocom also fabricates various quality resonators and oscillators. They manufacture direct and indirect type TCXOs, and oven-controlled crystal oscillators (OCXO). The OCXO uses an AT-cut resonator and achieves 5×10^{-10} aging rate after two days of turn-on. Toyocom just started some work on SC-cut crystals. The pursuit is on electronics, not on crystals, large-scale integrated circuits and reducing oscillator volume, both for TCXOs and OCXOs. In this enterprise they are very successful. Between 1980, they reduced TCXO volume from 40 to 2 cc, with similar results for OCXOs.

INSTITUTE OF ELECTRICAL ENGINEERS, JAPAN (IEEJ)

On 18 February 1986, I gave a seminar talk "Radiation Effects in Quartz, Resonators and Oscillators" to the Committee for Application Technology of Precision Frequency, IEEJ. This group is chaired by Professor Oura, TIT. Approximately 40 people attended. I talked for one hour with an additional thirty minutes devoted to questions and answers. In general, there is an adverse Japanese reaction to any work related to radiation effects, but

I do believe that the talk was well-received. The Japanese do plan to deploy communication satellites containing time and frequency control devices, and radiation effects on acoustic and electronic devices is becoming a legitimate topic of investigation. (This topic was further discussed during my visit to NTT, the company responsible for designing the communication satellites.)

The meeting took place at the Research and Development Laboratories of Kokusai Denshin Denwa (KDD), the company responsible for developing international telecommunication services. I did not schedule a visit to KDD, but I do have a brochure describing their R&D activities. Programs at KDD of special interest to us include fluoride glass optical fibers and the development of laser diodes. The theoretically predicted absorption loss of a fluoride glass fiber in the 2 to 4 μ wavelength region is two orders of magnitude smaller than for a comparable silica glass.

NIHON DEMPA KOGYO (NDK)

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In crystal products NDK is the chief competitor of Toyocom. NDK product line includes cultured quartz and gem stones, ADP, KDP, and optical blank components; resonator units for industrial and consumer use including tuning fork, cold weld, micro AT-cut strip, resistance weld, and solder weld type resonators; crystal units for microprocessors; VCXO, TCXO, OCXO, and high precision oscillators; crystal, SAW, linear phase, and monolithic filters; and ultrasonic probes. NDK is also the authorized supplier to the National Space Development Agency of Japan (NASDA) for satellite-deployed crystal products. NDK employs 900 people, all in crystal-based technology.

I visited the NDK Technology Center, the Sayama Plant. Quartz processing and resonator fabrication is at the Furukawa plant. An affiliate company, Hawk Denshi, located near Niigata, also fabricates crystal resonators. Another affiliate, Asian NDK Crystal, is located in the Sungei Way Free Trade Zone, Selangor, Malaysia. This company was established in 1979 and takes advantage of the lower pay scales prevailing in Malaysia. Low technology production items are farmed to Malaysia; for example, crystal blank cutting and manufacture of some crystal resonators.

At the entrance of the Sayama Plant there is on display a Brazilian natural quartz stone which is the largest quartz crystal I have ever seen. It is 1.8 m high, has a perimeter of 3.4 m, and weighs 3.6 tons (8000 lb). It dwarfs, by comparison, the crystal displayed at the entrance of NBS, Boulder, Colorado. Dr. Ohtomo, now on the Board of Directors, is one of the initiators of the quartz industry in Japan, has done significant development work and is still active in product development. In most factories, company uniforms are worn

even by supervisory personnel. Similarly, in Japan most offices are not entered with shoes. Slippers are provided, and shoes are checked at the entrance.

NDK uses several autoclave sizes for crystal growth. They have 4250 l capacity units, 60 cm inside diameter by 15 m, running at 1500 atm. Growth is in a NaOH solution at a growth rate of 0.6-0.7 mm per day, with the temperature differential between the bottom and top portions of the autoclave maintained at 50°C. A typical growth runs last 45 days. Each of these units produces two tons of crystals per run. NDK adds a lithium compound to the nutrient. NDK prefers to grow in a sodium hydroxide solution, as the sodium carbonate solution accelerates crystallization. NDK crystals are about 8" long and are wide enough for standard 5 MHz, fifth overtone, resonators. NDK quartz quality is slightly higher than Toyocom, and both are better than Kinseki. NDK is interested in improving quartz quality, as long as they can maintain current growth rate. Neither NDK nor Toyocom sweep (electrodiffuse) crystals, a standard practice for high precision oscillator applications in the U.S. Emphasis is on the mass produced commercial market, and not on high precision applications.

One current research issue relates to the point defect structure of cultured quartz is that substitutional aluminum is compensated with sodium, or lithium, but not with hydrogen. Other hydrogen related defects do form during growth, but the Al-OH defect, observed after irradiation or sweeping, is not observed in as-grown quartz. Ohtomo conjectures that the initial defect center in quartz is formed by the hydroxide, and that sodium, or lithium, is introduced as a consequence of hydroxide centers. The sequence then requires, or allows, the aluminum to be incorporated. When the Al is incorporated, all hydrogen related impurities are already compensated which precludes the formation of Al-OH.

At NDK, crystal characterization includes room temperature infrared scans at 3585 and 3800 cm^{-1} , deep etching and etch pit counts, and x-ray topography. Previously, in a cooperative effort with NEC, NDK has correlated infrared measurements with 5 MHz, fifth overtone, resonator Q-values. Consequently, for quality control purposes now they find it sufficient for each autoclave run to perform infrared scans on selected crystals. I toured the resonator fabrication and manufacturing area from the outside. All work is done in clean rooms, and I was not invited to enter. Rooms are color coded and painted white, yellow, green, and blue, consistent with their clean room rating. All personnel working in these areas wear color-matched clothing, and tools and equipment are also color matched to the specific room.

Crystal blanks are cut and shaped in Malaysia, but most resonator fabrication is performed in Japan. I noted at NDK, and at other Japanese facilities, vast quantities of U.S. test equipment, specifically Hewlett-Packard instrumentation. Similarly, the resonator testing equipment used by NDK is manufactured by Saunders and Associates, the standard instrumentation at U.S.-resonator fabrication centers. A batch of 300 TCXOs are temperature soaked and characterized at the same time. NDK TCXOs are rated ± 1.5 ppm between -40 and +85°C, ± 0.5 ppm between -10 and +50°C, and have aging rates of $\pm 0.2 \times 10^{-6}$ per year. NDK designed their TCXOs and incorporated integrated LSI technology, ICXO. The largest ICXO customer is the automobile industry. Another new quartz, and resonator, application is optical material for compact disk players.

Oscillator design is done at Sayama, but manufacturing is at subsidiary plants. NDK OCXOs are of conventional design, with aging rates of 5×10^{-10} per day after one day of operation. NDK started to develop the SC-cut crystal. They find the usual problems of

crystallographic orientation sensitivity, large b-mode impedance, and anharmonics. At the present time, NDK does not have unique solutions to these problems.

NIPPON TELEGRAPH AND TELEPHONE (NTT) CORPORATION

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Mr. Kazuo Kiuchi

NTT Electronic Communications Laboratory (ECL) (now called Research Centers) is responsible for developing telecommunications-related technologies and systems, as well as basic research essential to the long-term interest of NTT. As a result of the intensifying trend toward merging communications and information processing fields, NTT is constructing an Information Network System (INS), and the ECL is tasked to promote progress in:

- an all digital network,
- intelligent machine processing techniques,
- nanometer and nanosecond technologies, and
- advanced optoelectronics.

The ECL was recently reorganized into nine functionally-oriented laboratories (research centers) located at Atsugi, Ibaraki, Yokosuka, and Musashino.

Atsugi Research Center focuses on developing VLSI technologies, optical semiconductor elements, compound semiconductor devices, GaAs growth and ICs, superlattice devices, materials and manufacturing equipment, microcircuit processing technologies, and LSI design methods utilizing CAD systems. Ibaraki Research Center emphasizes optical materials and components, plant engineering, and construction, installation, and maintenance of optical fiber networks for INS. Basic technology work includes optical fiber materials, splicing fibers, constructing optical fiber cables and waveguide components. Solar cells, and organic and inorganic materials are expected to play vital roles in telecommunications as well as activation analysis, and the growth of zirconium fluoride glasses for infrared optical fibers. Very low loss zirconium fluoride fibers are important in developing long-haul transmission systems.

The Yokosuka Research Center includes radio communications network, communication and information processing, integrated communications, and the software production technology laboratories. Radio communications laboratory focuses are in network digitalization, terrestrial, mobile, and satellite communication systems, and communication satellite components. The communication and information processing laboratory performs research in integrated communications, information, and intelligence processing for enhanced INS. Also, microcomputer software and hardware, facsimile and videotext communications, media conversion, and artificial intelligence (AI) as related to expert systems and natural language processing. Integrated communications laboratory activities relate to services, work stations, and terminals to be used in INS business office segments, including digital telephone sets, video conferencing and image processing, on-line handwritten character recognition, and human-machine interfaces. The software

production technology laboratory develops technologies for improved software, with focuses in language processing, multitarget function Ada compilers, INS integrated software, automatic testing, and management systems.

I visited the Musashino Research Center, which employs approximately 2000 people. Located at this site are the R&D headquarters, telecommunications network, basic research, and electronics and mechanics technology laboratories. Telecommunications network laboratory develops network architecture, digital and packet switching systems, INS model pilot plant operations, and very large capacity optical fiber, subscriber loop, and submarine optical cable transmission systems. Basic research laboratory supports telecommunications and information processing technologies and contributes to broad advances in science as a whole. It establishes new knowledge in materials and physical characterization, expert systems, nonlinear quantum optics, superconductive devices, speech articulation, and chemical vapor deposition apparatus for growing pure GaAs and AlGaAs. Electronics and mechanics technology laboratory develops electronic and optoelectronic components and equipment, computer communication, power supplies, robotics, and material characterization. Developments include magnetic disk memory systems, transceiver modules for fiber optic subscriber systems, surface characterization using synchrotron radiation, automatic precision polisher for silicon wafers, and an ultrasonic wave device for detecting deterioration of wooden poles.

Dr. Jumonji is with the electronics and mechanics technology laboratory. He and his coworkers have developed crystal and atomic beam resonators, oscillators, and clocks. The cesium beam frequency standard marketed by Fujitsu was designed and developed by NTT, and transferred for fabrication to Fujitsu and NEC. This cesium standard uses FET amplifiers instead of multipliers, is partially modularized, and is expected to have an estimated MTBF of ten years.

NTT is fabricating low power and small-sized digitally compensated TCXOs for mobile communication systems. This is implemented by developing LSI circuits and a TCXO structure suitable for CMOS integrated circuitry. The TCXOs are in production, are temperature compensated between -20 and $+70^{\circ}\text{C}$ to 0.5×10^{-6} , and have an overall accuracy of 1.5×10^{-6} . The resonators for these units are fabricated by Toyocom.

NTT is developing a multibeam communication satellite, and Jumonji is designing the space deployable oscillator. The oscillator operates at 8.192 MHz, is hybridized, and is ovenized using a kovar-iron alloy flask. The frequency-temperature coefficient between -20 and $+50^{\circ}\text{C}$ is 1×10^{-9} . The Allan variance at 1 s is 4×10^{-12} , and the SSB phase noise at a 100 Hz offset is -135 dB. Oscillator dimensions are $8 \times 11 \times 15$ cm, 80 in³, and weighs 950 g. Power consumption design goal is 3 W during warm-up from -20°C , and 1 W for steady state operation. The SC-cut resonator used to minimize thermal shock, and to obtain a low aging rate, is fabricated by NEC from Toyocom quartz. Frequency offset radiation specification is 2×10^{-7} for an accumulated 1 Mrad dose in ten years.

YAMANASHI UNIVERSITY

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Professor Masahiro Hosaka, Institute of Gemology and Jewelry Arts

Dr. Junichi Yoshimura, Institute of Inorganic Synthesis

Professor Taki initiated cultured quartz growth in Japan in 1953. He is now 62-63 years old, and will retire at the age of 65. Industrial production of quartz started at Toyo in 1960, and Taki was employed at Toyocom (Toyo Communications Equipment) between 1962 and 1972, after which he returned to Yamanashi. Hosaka, a former student of Taki, is an assistant professor at the Gemology Institute. (Asahara, the general manager of crystal growth at Toyocom is also a former student of Taki.) Taki and Hosaka coauthored several papers on growth and characterization of quartz.

Quartz investigations at Yamanashi include the growth of pure crystals, growth in pure water and NaCl and KCl solutions, grown by reverse temperature gradient method (at low filling), effects of impurities, growth of colored crystals for gem stones, formation of iron and cobalt compounds, and characterization by infrared absorption, x-ray diffraction, and topography. In a series of fundamental crystal growth experiments, Hosaka and Taki investigated systematically the growth parameters of quartz, including growth in pure water and NaCl and KCl solutions. Results of these investigations, including the low temperature infrared hydroxide spectra of these crystals, were published in a series of papers in the *J. Crystal Growth* and in the *Proc. 35th ASFC* in 1981. Subsequent to these experiments Taki grew high purity quartz, 100 ppb Al, from a pure silicate glass nutrient which was converted to quartz under proper hydrothermal conditions. Current programs emphasize inclusions. The standard inclusion of interest is acmite, a sodium-iron-silicate compound, $\text{NaFeSi}_2\text{O}_6$, which can form during growth. The addition of a lithium salt to the nutrient, a standard practice at U.S. crystal growth facilities, minimizes acmite. Taki is also investigating other microscopic inclusions observed in commercial growth, specifically, emeleusite, a lithium-sodium-iron-silicate compound, $\text{Li}_2\text{Na}_4\text{Fe}_2\text{Si}_{12}\text{O}_{30}$, found even in lithium salt grown quartz.

Taki and Hosaka have performed some very intriguing crystal growth experiments. In one case, the nutrient was placed at a very low temperature at the upper portion, and the seeds suspended at a higher temperature at the bottom portion of the autoclave. Transparent crystals were obtained for potassium, but not for sodium solutions. In another study, they determined z-, s-, and x-growth ratios as a function of aluminum impurity concentration. Hosaka, a professor at the Institute of Gemology, is very much interested in developing cultured quartz as a gem stone. This includes growth of colored quartz crystals, obtained by doping with Co, Fe, and Ti. A fascinating experiment is the growth of quartz on seeds suspended horizontally in the autoclave. This results in different inclusion patterns on the two seed surfaces, and possibly differences in extended and point defects.

In addition to infrared evaluations, crystals are characterized by optical microscopy, atomic absorption, differential thermal analysis, x-ray power diffraction, x-ray topography, and secondary electron emission. These investigations are under the supervision of Junichi Yoshimura. His laboratory is well-equipped for these measurements. His group also performs theoretical studies, including computer simulation of x-ray Laue patterns, diffraction rotation (zebra distortion), determination of the absolute structure of right- and left-handed quartz, and analysis of natural beryl and cultured berlinite crystals grown in their laboratory.

TOKYO METROPOLITAN UNIVERSITY

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Professor Yoshimasa Oomura
Professor Hitoshi Sekimoto

Professor Oomura is designing and evaluating resonators. He has published on frequency-temperature behavior of miniaturized disc crystals, CMOS crystal oscillators, and digital TCXOs. Oomura recently spent seven months with Professor E. Newell at Northern Illinois University, where he lectured on crystal resonator measurement methods. Oomura is a member of the Institute of Electrical and Communications Engineers of Japan Subcommittee on Quartz Crystal Measurement Methods. Professor Sekimoto is a theoretician and has published analyses on trapped energy resonators with circular electrodes and tabs, and on the design of monolithic crystal filters.

The problem of resonator design, and developing circuits, and practical experimental techniques for measuring precisely resonator frequency and other electrical parameters has engaged many investigators for many years. A classic paper on resonator characterization was given in 1974 by I. Koga, "Precision Determination of Parameters of VHF Crystals," *Proc. 28th ASFC*, 49 (1974). (In 1974 Dr. Koga was affiliated with KDD. Professor Isaac Koga was the original inventor of the AT-cut crystal in 1933, a year earlier than AT-cut developments in West Germany and the U.S.) The resonator characterization work was expanded by Dr. Koga, and in 1980 he published a monograph *Measurement of VHF Crystal Unit Using a FR-meter and an Auxiliary Reference Resistor*. Koga died several years ago and Oomura is engaged in refining, implementing, and automating Koga's characterization proposal. He submitted an abstract on this subject to the forthcoming Frequency Control Symposium.

Oomura has previously investigated digitally temperature compensated AT-cut crystal resonators. He has now obtained SC-cut crystals from NDK and will investigate digital compensation schemes for SC-cuts. Investigations on digitally compensated SC-cut crystals have been conducted in the U.S. since 1978.

Sekimoto is developing a theoretical framework to calculate strengths of third overtone anharmonic modes in transverse mode excited blanks as a function of geometrical configuration and resonator parameters.

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Fujitsu is the leading Japanese computer maker and one of the world's leading manufacturers of telecommunications systems and equipment. They employ over 60,000 workers in 13 plants in Japan, operate a variety of R&D facilities and overseas subsidiaries, and their annual sales exceed \$5 billion. I visited the Research Laboratory and Engineering

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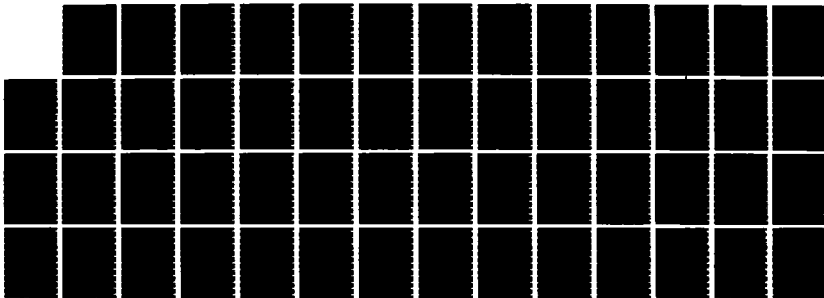
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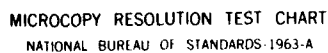
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Center at the Kawasaki Works.

The Electronic Components Group (ECG) produces monolithic filters and mechanical resonators using piezoelectric materials such as lithium tantalate, niobate, and tetraborate. For the last several years ECG has been concentrating on miniaturized chip-type frequency control devices compatible with integrated digitized electronics. In 1985, at the Frequency Control Symposium, they reported on strip-type resonators fabricated from lithium tetraborate. Y. Fujiwara, M. Ono, M. Sakai, N. Wakatsuki, "Strip-type Resonator of Lithium Tetraborate," *Proc. 39th ASFC*, 351 (1985).

The Transmission Group develops and fabricates miniature voltage and oven controlled crystal oscillators, rubidium atomic resonance controlled resonators, and cesium beam frequency standards. At the present time, they are the only Japanese manufacturer selling atomic frequency standards. They fabricate the frequency standard but not an atomic clock. In 1985, at the Frequency Control Symposium, they reported on an ultraminiature rubidium frequency standard, [K. Chiba and T. Hashi, *Proc. 39th ASFC*, 54 (1985).]

ACKNOWLEDGMENT

I would like to acknowledge the invaluable help provided by Dr. Yoon Soo Park, AFOSR Liaison Office, Far East and by Mr. Tsugio Satoh, the ONR Science Advisor. They made and confirmed arrangements, provided detailed transportation instructions, joined me on some visits, and guided me in dealing with cultural differences. The assistance provided by this Air Force office and personnel was of considerable advantage, and contributed significantly to the efficiency of my visit as well as to peace of mind, a very important consideration in a country where I was unable to read even a street sign. I may have outlasted my welcome, but I do appreciate their support.

MEASUREMENT AND INSTRUMENTATION SYSTEMS CENTER ESTABLISHED IN AUSTRALIA

Peter H. Sydenham

INTRODUCTION

Information technology (IT) is a vital area in today's high technology world. The current emphasis in IT is on storage, retrieval, transmission and transfer of information. The less emphasized yet equally as vital component is that of obtaining reliable information.

Knowledge of the physical world is obtained by observation and measurement of parameters which combined with conceptual models establish relationships and facts. National wealth creation and improvement of social conditions require such measurements. Over the last two decades, the academic status of measurement science has been steadily improving to the point where recognized groups have been established in academic institutions, in some cases with the formation of new departments. With the acceptance that measurement science can be formalized, that measuring instruments can be better designed and applied by the use of a scholarly approach, an ever widening recognition of contributions has been made in this area. Maturity has now reached a point where interdisciplinary groups should be created to provide continuity in this development in order to support scholarship inertia now gained.

The current scarcity of funding in the academic sector prevents full-scale initiative from emerging as a routine development; consequently, new ways must be found to further the scholarship. One method that can contribute to measurement science in order to further its development is to form cross-campus centers that are actively linked in cooperative programs. Existing campus departmental structures can be used to support the growth period until sufficient resources begin to flow to enable the activities to stand alone.

FORMATION OF A CENTER IN SOUTH AUSTRALIA

A center providing an international focus for developing scholarship for measurement science and instrument engineering has been created at the South Australian Institute of Technology, (SAIT). The center is situated on the Levels Campus of SAIT, some seven miles from Adelaide, the capital city of South Australia. It is called the Measurement and Instrumentation System Center (MISC). At present, several academic centers of excellence in measurement science exist in the Northern Hemisphere. This is the first in the Australian-Asian region.

Strong ties and cooperative programs have been established with many of the northern groups enabling MISC to provide, to regional participants, an informed service that is based on both global, and MISC state-of-the-art research and development contributions.

Advances in this subject area need to be directed to assist the practical design and application of needed measurement systems. The applied nature of the South Australian Institute of Technology activity makes it a suitable campus for this development. Interaction with occupants of the adjacent Technology Park, Adelaide, Australia's most successful science park, strengthens the opportunity to be closely involved with commercial and scientific application of instrumentation.

By making use of the existing, already extensive, campus experience in contract research, industrial consultancies, teaching and strategic research, MISC was able to begin operations in late 1985 as an already mature organization.

- The SAIT Plan for Measurement Systems Engineering Development

The Center is the first step of a long-term, three-stage plan. These steps are:

- . establish scholarly academic activity under the structure of the Measurement and Instrumentation Systems Center,
- . develop an advanced concept, campus-based training company to produce suitably skilled, and supported executives in measurement systems development and application, and
- . through these people spawn new start up measuring instrument concerns that use MISC for their academic foundation and research "umbrella."

These three steps provide an efficient flow-through from intellectual scholarship into independent, successful commercial enterprises.

New enterprises developed and supported in this way will have enhanced opportunity to trade profitably because they will:

- be operated by purpose-trained staff,
- use advanced design aids,
- use a structured design methodology tailored to measuring instrument realization, and
- be supported by an international center devoted to the fundamental R&D needs of their industry.

- Main Objective

The activities of MISC pursue one underlying objective--that of identifying and applying the necessary fundamentals of measurement science in order to obtain cost-effective, accurate measurement systems which are formed by scientifically-based engineering procedures.

Measurement systems, despite their apparent diversity, can be realized by the use of standardized procedures and building blocks that are largely common to most kinds of measurement tasks. Using this philosophical approach, it is possible to construct measurement systems from the "top-down" in a highly structured manner.

Three key areas of activity are fundamental to success in achieving the objective. These form the groupings of effort within MISC.

- . Application of computers in the selection, design and operation of measurement subsystems and systems.
- . Selection, design and application of sensors in traditional, microelectronic and fiber optic forms.

- Streamlining the realization procedures of the signal handling hardware needed for conditioning, transmission, storage and display of information procured by sensors.

The kinds of MISC activities include:

- strategic R&D to further instrument engineering,
- development of CAD tools,
- generation of suitable data bases,
- prototype instrument building and testing,
- instrument evaluation,
- provision of expert advice,
- assistance with development of national policy,
- conducting application and evaluation studies,
- organizing conferences, seminars and courses, and
- editing and publication of papers, texts and reports.

MISC provides an appropriate academic atmosphere for the generation of new ideas. Persons associated with the Center are able to acquire high levels of understanding of the ethos of the instrument industry, and it provides a lasting growth entity by identifying the available expertise (which is considerable across the SAIT campus) as an on-going infrastructure.

Specific, applied measurement systems are also designed by contract. These provide realistic situations for the gradual development of generalized design procedures. Each new design start up is able to benefit from the then available state of the specialized know-how that is constantly being accumulated in the Center.

Much of the Center's work is already, and will be more so as MISC develops, in the commercial domain (software sales and licenses, design service, courses, consulting contracts, etc.).

The concept being invoked to financially support the Center is that scholarship can be assisted by commercial contract if the contract work can be fitted into a well-orchestrated longer-term plan. Fortunately, in this discipline, the scholarship needs closely match the commercial requirement: improved design and application will result from more formal study of measurement systems. In due course it is intended, using the international data networks, to provide an on-line instrument design assistance service.

Educational activity is important for the effective transfer of the knowledge generated by the Center. An important facet, therefore, is the development of teaching programs, for both Australian industry and science and for adjacent Southeast Asian regional countries.

An important characteristic of the instrument industry is that a design can be developed and marketed by relatively small commercial operations that have high "brainpower" content and considerable drive by individuals. Short, design-to-sales lead times are essential and innovation is vitally necessary. Such issues are paramount in the development and operation of the Center and its methods.

The objectives of MISC are advanced with the assistance of the Adelaide Innovation Center, Technology Park, Adelaide (TPA), the South Australian Microelectronic Applications Center, the SAIT Microelectronics Center and with other suitable mechanisms

that nurture commercial initiatives each of which is on the joint South Australian Institute of Technology--Technology Park, Adelaide campus at the Levels.

Already an associated industrial design unit (IDU) (initially state government-supported) and an expert systems applications group (ESAG) (industry, Techsearch and School of Electronic Engineering supported) have been spawned since MISC began in late 1985.

A project, just begun, aims to create a much needed Regional Flow Meter Test Center using the already existing SAIT Hydrology Laboratory.

- Administration and Management

An academic-in-charge (the author) is responsible for developing and directing the Center's long-term objectives, and is assisted by a coordinator (Dr. Richard Thorn) who has the task of making it work on a day-to-day basis. Both persons are actively involved in both teaching and R&D.

No priming grant was used to start the Center. It was begun as adjuncts to the academic duties of both persons. Whilst this may not be the fastest way to proceed, it does give some degree of surety that the Center will have time to develop to a point of self-sufficiency.

Management support (currently provided by the School of Electronic Engineering) will be provided from income as growth permits. Contract engineering staff are already being engaged to support particular projects.

- Advisory Board

An advisory board of management exists comprising senior persons in private firms and companies, academia and public agencies.

The Board meets three times per year; to review the proposed program and budget for the Center on an annual basis; to monitor and review activities; to forward a report of activities to the institute directorate in June and December each year and to approve an annual report.

- Financial Arrangements

Commercial aspects, such as consultancy charges, intellectual property management, patenting and salaries of sponsored staff, are dealt with by the institute's campus company, Techsearch, Inc. It possesses extensive financial, administrative and contract experience.

Grants and contracts to named persons are administered by the named recipient. However, where the Center has clearly been instrumental in helping secure the resource for that person then a small contribution, usually as occasional assistance, is required to be given to Center operations.

RESEARCH STAFF AND THEIR MISC PROGRAMS

To date the majority of the R&D work so far assembled (some 20 man-years of commitment over the next two years, was forthcoming in the first four months) is being

carried out by research workers connected with firms. These persons conduct their programs both on campus and within the firm's establishments. Generally, MISC locates the staff for the firms and assists in setting up the projects.

- Associates of MISC

The scholarship activity of MISC is developed by persons who associate their work with MISC via annual registration. These people provide supervision of students, consulting time and are engaged in specialized measurement science work of their own.

Associates of the Center are able to make use of the knowledge of the Center and its informal network of people, use specialist equipment, the growing ensemble of specialized CAD software and have access to purpose-built data banks and library material which also is steadily growing in magnitude. Another incentive to be associated is that their particular aspirations are then supported and promoted by MISC in its dealings with clients.

To gain associateship, a person (on and off campus) must contribute to the scholarly development of MISC in a material and significant manner. They must be prepared to allow defined work to be listed in reports and proposals and assist with enquiries made to MISC. This formality is needed to ensure that MISC is efficient and accurate in its reporting and marketing operations.

Agencies that use MISC services to achieve routine commercial gain are termed "sponsors." They support the Center through consulting contracts, grant provision or through the supply of staff members. Associates of MISC generally direct and take part in the higher levels of team R&D. They also, on a more personal basis, conduct a miscellany of smaller specialist tasks as they arise.

Some recent examples of small contracts are the production of the basic design for a sensor to be marketed, evaluation of the assets of two firms about to form a public company, design of a car parking control system, creation of a time-lapsed camera control to photograph Halley's comet and technical evaluation of bar code readers.

Associate's main research areas include computer-aided engineering (CAE) of instruments, expert systems applied to instruments, flow measurements, optical fiber sensors and wind energy surveying.

A major project in progress is the development of a highly-structured measurement and control system for selection and application by untrained persons. The aim is to provide low cost, highly reliable instrumentation for use in small businesses. This program is carried out in conjunction with a CAD experienced local firm and the Control Group of the School of Electrical Engineering of SAIT. Commercial partners in regional countries, the source of the project idea, are expected to be involved shortly.

Another large project area is in the whole system design of hearing aids. A long established firm is involved as the commercial partner. This is a joint project with the SAIT Micro Electronic Center (MEC) who are able to provide state-of-the-art designs for system circuitry in the silicon form.

Another industrial relationship is concerned with improving pulse power supplies for laser equipment. This project will use the advanced software available in MISC to model the system components as electro-thermal-mechanical assemblies. This enables simulation

of the system during nanosecond pulse duration.

MISC also assists in the development of the publication side of measurement science. It edits and produces the quarterly, *Australian Journal of Instrumentation and Control* for the Institute of Instrumentation and Control, Australia (IICA) and manages the Editorial Board of the John Wiley and Sons (U.K.) new book series on *Measurement Science and Technology*. MISC prepares articles and reviews and provides referees for learned paper assessments.

Associates develop these programs to the common good of each need. A surprising degree of synergy that has already resulted from each project has had considerable overlapping requirements.

- Visiting Experts

A significant source of expertise offered by MISC is the visiting expert coming from an overseas country. In 1986, plans are in various states of preparedness to support the visits of six specialists from the U.K. and the U.S.A. Support for these people is usually generated, through MISC, by their involvement in short courses and consulting work. Visiting workers are afforded appropriate recognition and are provided with use of campus facilities.

- Visiting Scholars

Requests for special training programs can be accommodated: the Center will design the training needed to suit the client's requirements. By way of example, in July 1986, the person responsible for development of primary and secondary school physics teaching apparatus in Thailand will join MISC as an ADAB fellow for five months to learn instrument design principles.

- Doctoral and Master's Degree Programs

MISC has a Ph.D. student enrolled in the TCU, London, center mentioned above. Using this mechanism, MISC can be engaged in enhanced Ph.D. programs in which leading edge contributions of both are combined.

Both centers specialize in the development of computer-aided engineering (CAE) of instrument systems. The first enrollment is on a subject for development of an intelligent knowledge-based system (IKBS) for assisting the generation of instrument system specifications called SPECRITER. It will soon be followed by a second thesis topic that develops CAE for organizing the management of the design of instrument systems.

At present, the majority of the research work is carried out by master's (by research thesis) students. These are generally on a topic that has been requested by an external sponsor and, as such, the students have particularly close contact with their sponsor's establishment.

The current, dominantly Australian citizen group of students will soon include more people who have been nominated by a regional country, commercial ventures, and government agencies. These will come to MISC as the result of several large, peer-relationship R&D programs that are developing in instrument product areas.

- Use of Final Year Project Students

Final year electronic engineering degree students take part in MISC programs. In 1986, five topics cover the development of CAD tools for designing, temperature, flow, and certain chemical sensors and the nature and content of intelligent instrument systems in which skill is embodied in the software.

In this work, the CAD software, available within MISC for mechanical, electronic and physical response simulation, will be brought together to form an integrated software tool by "user interface" software and expert systems techniques. It will also be used to guide a user to select and commission a measurement and control system.

Through the development of electronically stored "all domain" designs and designers tools, MISC believes it will enhance performance, lower design costs, greatly reduce lead time to product and bring about a more organized structure to the application of sensing systems.

- Specialized Courses and Conferences

Another line of considerable effort being expended within MISC is the generation of a strong short-course program. Action is underway to bring, within the next 12 months, overseas speakers into Australia to give courses in optical fiber sensors, international consultancy operations in the instrument discipline, expert systems applied to industrial sensor and control systems, flow measurement, electro-optical device design and manufacture, and instrument design.

Associates and MISC central staff are also generating a course on sensor design with the emphasis on microelectronic forms and are developing an international, Adelaide-based Conference on Measurement Science for 1987. This is intended to be the forerunner of a regular annual conference.

- Developing Regional Relationships

Assistance is being given to the Australian Federal government Scientific Industries Steering Committee (SISC) of the Department of Science. This program aims to develop training and cooperative R&D in measurement science and technology with ASEAN country members and other regional countries.

MISC also expects to take a significant part in the recently approved, \$A2.6 million ASEAN/ADAB Microelectronics Training Program. Several countries have expressed interest in the applications engineering aspect of instrumentation development which is the main focus of MISC activity.

SPECIAL FACILITIES

Special facilities; for instance, flow meter test rigs, environmental test chambers and instrument evaluation procedures, require considerable equipment and staff support. These are being developed as circumstances allow. Some are already in place from programs of institute schools.

These include plants such as the National Association of Testing Authorities (NATA) registered 50 m towing tank, a vibration strong floor with computer-controlled rams, wind

tunnels, chemical analytical equipment, anechoic chambers, NATA-registered high voltage and metrology laboratories and the CAD-based electronic chip development service (including a rapid turn around, semicustom, gate array service) that has specific expertise and software for sensor and analog system realization in thick film and silicon forms.

TIES WITH OTHER MEASUREMENT GROUPS

MISC has many overseas connections. These have come about as the result of past activity. Since the creation of MISC, many others are developing.

- Several U.S. Links are in Operation

In the Instrumentation Technology Department, Texas State Technical Institute, Waco, Texas, Professor Donald Gillum has assisted publication work of MISC that was taken up by the Instrument Society of America (ISA). He has extensive experience with measurement education. The ISA has published three books by the author of this paper.

In 1985, a Measurement and Control Engineering Center was formed as a consortium activity between industrial sponsors and the University of Tennessee and the Oak Ridge National Laboratory. This Center, through the services of Professor T. Kerlin as an editorial board member, provides assistance with the John Wiley book series managed by MISC staff.

A long-standing tie exists with the consultancy, H. L. Daneman and Associates, Sante Fe, New Mexico, one of the few specializing in international metrology. They are skilled in product surveys, laboratory establishment, apparatus development and training for instrument product development. An agreement to develop several areas of joint activity has been reached in which MISC and this consultancy practice will seek to fulfill international funding agency needs.

A joint paper was recently read by Mr. Daneman and the author at the Measurement Science Conference held in Irvine, California, January 1986. The theme of the paper was a review of the international cooperation that already exists and can soon be expected to exist in measurement science.

More developed ties exist with groups in the U.K. There the Science and Engineering Research Council (SERC) supported a specially promoted program (SPP) for measurement and instrumentation. Four groups were funded over a three-year period. These were:

- . The City University, London (TCU) (physical description and design of transducers, ultrasonics, pattern recognition),
- . University of Warwick, Coventry (microengineering),
- . University of Bradford, Bradford (process control instruments, biomedical),
- . University of Manchester Institute of Science and Technology (UMIST), Manchester, (analytical instruments, optical fiber sensors, ultrasonics, physical transducer systems).

- Department of Instrumentation and Analytical Science, (DIAS), UMIST

This postgraduate department was established in 1978. It began with three chairs and five other teaching staff. It trains M.Sc. and Ph.D. postgraduates in measurement science and has grown to have, in 1986, some 150 persons engaged in the R&D of instruments.

A formal "school-to-school" agreement of cooperation has been recorded. MISC students can enroll in Ph.D. studies with this group doing some of their work in Adelaide. Staff exchange has taken place with a recent visit by Dr. Spooncer, an expert on optical fiber sensors. His visit was supported by a British Council Link grant that assists cooperative operations.

- Measurement and Instrumentation Center, The City University, London

Within the School of Electrical Engineering and Applied Physics is the Measurement and Instrumentation Center. It concentrates on fundamental concepts of measurement and instrumentation, ultrasonic instrumentation with special applications to nondestructive testing, computer-aided design of transducers, fiber optical sensors and signal and image processing.

This group was one of the first to develop what can be regarded as the scholarship aspects of instrument systems understanding. It has a long, very close partnership with the Sira Institute, U.K.

This group is the source of the physical system simulation software, MEDIEM, that MISC is currently commissioning as part of its integrated software system.

- Sira Institute

A association exists with the Sira Institute, U.K. and MISC is a member of their Expert Systems Club in order to keep abreast of developments in this area, one that has been identified as vital to the streamlining of future instrument design.

- Human-Computer Interface Research Unit (HCIRU), Loughborough University, U.K.

Measurement systems are interfaces to the real world for both human and nonhuman events, so this is a useful and relevant cooperation.

User interface software, SYNICS, having a modest expert systems ability, has been provided by the HCIRU. This software is being used by MISC to assist implementation of design methodology in computers. A derivative form of SYNICS, that developed by Unilever Research Laboratories, Port Sunlight, U.K., has also been acquired by MISC to assist in its programs.

These overseas relationships have been valuable. They have greatly helped MISC to develop. While initially relying much on their assistance, MISC is now in the position to return to them assistance in the form of software, results of research programs, and financial support of various kinds.

In turn, MISC is now able to provide assistance to regional country groups who would wish to work with the associates of MISC.

FURTHER INFORMATION

Further information can be obtained from either Professor P. H. Sydenham or Dr. R. Thorn at:

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ACKNOWLEDGEMENT

The author wishes to express gratitude for a grant from the Air Force Office of Scientific Research, Far East that enabled him to attend the Measurement Science Conference in California, U.S.A. Such grants greatly assist the development of beneficial cross-country linkages.

GOVERNMENT-SPONSORED RESEARCH IN INDUSTRY THROUGH THE JAPAN KEY TECHNOLOGY CENTER

Tsugio Satoh

INTRODUCTION

The government-sponsored Japan Key Technology Center was jointly established last year by the Ministry of International Trade and Industry (MITI) and the Ministry of Posts and Telecommunications (MPT) to help promote basic research and development of new technologies by civilian enterprises. Legal background and organization of the center is described in a National Science Foundation report (NSF/Tokyo, Report Memorandum #91) in great detail.

In a fiscal year 1985 budget, the center formalized its subsidizing program for the development projects. Twenty-five large-scale projects related to studies concerning outer space utilization, proteins, system development for fiber-optic communications and machine translation, etc., (total budget of 2 billion yen, Table 1) will require five to ten years of joint R&D effort by a number of enterprises.

Divided into four categories are the salient features of these projects which are introduced in this report:

- information and communication systems,
- biotechnology,
- advanced materials, and
- optoelectronics.

INFORMATION AND COMMUNICATION SYSTEMS

A new organization, the Advanced Telecommunications Research Institute (ATRI), was established in Osaka in late March 1986 to consolidate four development projects; audio-visual mechanisms, automated translator telephones, communication systems, and optic-radio communications. The ATRI has set up four R&D corporations with 70% of its capital from the Key Technology Center and 30% of its capital from 41 private enterprises, including ATRI, to begin those four projects. One reason for this structure is to disperse the risks involved in such basic research. As for human resources, excellent researchers will be dispatched from the Nippon Telegraph and Telephone Corporation (NTT), MPT, the Kokusai Denshin Denwa Company (KDD), Nippon Hoso Kyokai (NHK) and other private sector organizations to form an "open institute." It is noted that the subsidy for those projects is about a quarter of the center's total outlay.

- Audio-visual mechanisms

The investment for this seven-year project totals 14 billion yen. Audio-visual mechanisms, such as pattern recognition, will be studied from a man-machine perspective.

- Automated translator telephone

This is a seven-year project with a 17 billion yen investment. Research on voice recognition, machine translation, and voice synthesis will be carried out in order to realize translated telephone conversations.

- Communication systems

A ten-year project with 17 billion yen to furnish communication software.

- Optic-radio communications

A ten-year project with a 17 billion yen investment. Basic research will be done on communication between vehicles in transit.

The new organization for integrated research of outer space utilization will develop testing facilities to study the environment under micro gravity and its applications.

The research institute that is involved in electronic dictionaries studies will systematically sort out and organize various linguistic data in the computer to enable it to recognize words used on a daily basis.

Included among the major MPT-related R&D projects is a preliminary feasibility study of the ministry's "Teletopia" concept. This concept is aimed at creating a "city of tomorrow with a communications system to match." To this end, development efforts will concentrate initially on seven urban areas selected from the 34 areas that make up the project's first phase to provide each with a special communications systems to transmit information on tourism, various industries, and civic emergencies.

BIOTECHNOLOGY

Two R&D-type facilities are being set up. One is the Protein Engineering Laboratory (ten year project, 20 billion yen) and the other is the MD Research (six year project, 1.7 million yen) Laboratory.

- Protein Engineering Laboratory

Correlation between protein's structure and its functions will be studied aiming at designing/synthesizing high-quality protein. The laboratory will be established in Osaka with the support of 15 companies including Mitsubishi Chemical Industries, Kyowa Hakko Kogyo, Toa Nenryo Kogyo, Takeda Chemical Industries and Toray Industries. Y. Ito, Toray Industries, is scheduled to assume the presidency of the laboratory.

- MD Research Laboratory

Two existing companies, Meiji Seika and Daicel are establishing a new "joint" company (MD) to create high-quality peptides using genetic and chemical synthetic methods. The research focus is aimed at the mass production of peptides using the liquid phase method. It is also planned to isolate specific peptides from protein chains.

ADVANCED MATERIALS

There are two facilities planned in the field of materials research. They are the Nonoxide Glass R&D Laboratory (five year project, 720 million yen) and the Research Institute of Metals of High Performance Surfaces (seven year project, 4 billion yen).

- Nonoxide Glass R&D Laboratory

Nippon Sheet Glass and Hoya Corporation noticed the crystal properties of sulfur and selenium compounds and decided to set up a corporation to fabricate optical fiber for energy transmission using infrared rays. At the same time, this R&D corporation aims to develop an erasable optical disc using nonoxide glass.

- Research Institute of Metals of High Performance Surfaces (RIMHPS)

Seventeen steel and heavy-industry oriented companies have set up a research facility. Surface improvement technology, such as chemical vapor deposition and ion injection methods, will be applied to structural materials such as iron and aluminum. The application should yield improved steel toughness against abrasion, corrosion, and thermal deterioration as well as provide other added value.

OPTOELECTRONICS

- Optical Memory R&D

MITI's Agency of Industrial Science and Technology has been promoting a large-scale project called the "optical measurement and control system" which ended in fiscal year 1985. Its key technology was the development of optoelectronic integrated circuit (OEIC) elements. OEICs are new functional elements having features of both optical and electronic elements combined by integrating both elements on a single substrate. Results of the project in GaAs crystal growth technology will be utilized in this project aiming at second generation OEICs. At present, OEICs of 1 Gbit/s speed are being developed. The goals of the "planned" corporation is to produce 10 Gbit/s OEICs.

- Optics Measurement Technology Development

This corporation's goals are utilization of coherent optics measurement technology in optical communication systems to handle the increasing volume of information.

SORTEC

Thirteen companies, including Mitsubishi Electric Corporation, Toshiba, Cannon, and Sumitomo Electric Corporation have all gone in on this R&D investment which totals 10 billion yen. However, Sumitomo Heavy Industries and the Japan Steel Works have decided not to participate. Since the delivery by Sumitomo Heavy Industries of a cyclotron accelerator to Osaka University in 1972, the company has monopolized the market. They plan to develop a small-type synchrotron radiation facility (SOR) for ultra large-scale integrated circuits (ULSIs) microfabrication in three years. The specifications will be 1 m in diameter and provide 650 meV output.

Sumitomo Electric Corporation and the Electrotechnical Laboratory jointly developed a SOR of 4.2 m in diameter and 600 meV output. SORTEC plans to develop a 700 or 800 eV SOR in eight years. Competition in development between existing major companies and the planned corporations appears to be a unique feature in the field of synchrotron radiation facilities in Japan.

TABLE I

PRIVATE RESEARCH AND DEVELOPMENT PROJECTS
SUBSIDIZED BY THE JAPAN KEY TECHNOLOGY CENTER

PROJECTS	SUBSIDY (Millions of Yen)
Nonoxide glass	
Nippon Sheet Glass	35
Hoya Corporation	
Optoelectronic ICs (OEIC)	
NEC Corporation	100
Oki Electric Company	
Sumitomo Electric Industries	
Toshiba Corporation	
Outer Space Utilization	
Ishikawajima-Harima Heavy Industries	75
Toshiba Corporation	
NEC Corporation	
Hitachi, Ltd.	
Coherent Optical Communications	
Yokogawa Hokushin Electric Corporation	90
Advan Test	
Ando Electric Company	
Iwasaki Electric Company	
Anritsu Electric Company	
Active Peptides	
Meiji Seika	30
Daicel Corporation	
Protein Engineering	
Mitsubishi Chemical	200
Kyowa Hakko	
Takeda Chemical	
Toa Fuel	
Toray Corporation	
Image Information System	
Sumitomo Electric	80
Fujitsu, Ltd.	
Matsushita Electric Corporation	
Synchrotron Radiation Facility Design (SOR)	
Mitsubishi Electric Company	150
Toshiba Corporation	
NEC Corporation	
Hitachi, Ltd.	

	SUBSIDY (Millions of Yen)
Metals of High Performance Surfaces	
Nippon Kokan	35
Kawasaki Steel	
Nippon Steel	
Ishikawajima-Harima Heavy Industries	
Electronic Dictionaries	
Fujitsu, Ltd.	200
Toshiba Corporation	
Hitachi, Ltd.	
Oki Electric Company	
Audio-visual Mechanisms	
Advanced Telecommunications Research Institute	130
Nippon Telegraph and Telephone Corporation (NTT)	
Kokusai Denshin Denwa (KDD)	
Kansai Electric Power Corporation	
Automated Translator Telephone	
Advanced Telecommunications Research Institute	210
Nippon Telegraph and Telephone Corporation (NTT)	
Kokusai Denshin Denwa (KDD)	
Sumitomo Metal Industry	
Intelligent Communication Systems	
Advanced Telecommunications Research Institute	110
Nippon Telegraph and Telephone Corporation (NTT)	
Kokusai Denshin Denwa (KDD)	
Sony Corporation	
Optic-radio Communications	
Advanced Telecommunications Research Institute	105
Nippon Telegraph and Telephone Corporation (NTT)	
Kokusai Denshin Denwa (KDD)	
Toshiba Corporation	
Integrated Systems in Buildings	
Fujitsu, Ltd.	64
Shimizu Construction	
Taisei Construction	
Association-type Information Storage	
Carry Lab	20
MAC	
Crystal Soft	
T&E	
Common Backup Communication Networks	
System Brain	105

SUBSIDY
(Millions of Yen)

Seibu	
Dainippon Computer Systems	
BSN Eynet	
Miroku	
Wholesale Information System	
Takasaki	
Takasaki Wholesale Union	5
Takasaki Chamber of Commerce and Industry	
Gunma Bank	
Kumamoto Information Guide System	
Kumamoto Prefecture, Kumamoto	10
Kumamoto Daily	
Nippon Telegraph and Telephone Corporation (NTT)	
Active Local Information Systems	
Shimane Prefecture, Matsue	70
San-in Godo Bank	
San-in Central TV	
Suwa Broad Area Teletopia	
Nagano Prefecture, Seiko Epson	70
Okaya Chamber of Commerce and Industry	
Yamaguchi Triangle Teletopia	
Yamaguchi Prefecture, Yamaguchi	40
Hofu	
Ogouri	
Information Network, Fukushima	
Fukushima Prefecture, Fukushima	20
Fukushima Chamber of Commerce and Industry	
Nippon Telegraph and Telephone Corporation (NTT)	
Kurume Teletopia	
Kurume	30
Saga Bank	
Nishi-nippon Bank	
Kagoshima Videotex System	
Kagoshima Prefecture, Kagoshima	16
Minami-nippon Shimbun	
Minami-nippon Broadcasting	

ENGLISH-LANGUAGE INFORMATION SOURCES

Edward Mark Lenoe

INTRODUCTION

- Centers of Excellence, Key Societies and Associations

Japan literally abounds with learned and professional societies and associations! For example, the Science Council of Japan prepares an edition of their *Directory of the Learned Societies* approximately every five years. Their 1981 edition lists more than a thousand major societies as well as more than two thousand university based groups. As far as types of societies are concerned, using 1981 data, the largest number (363) is in the humanities, next comes medicine (271), third is engineering (163), then natural sciences (136), and next agriculture (66). Some of these organizations are quite large while others are small specialized groups. Largest is the Japan Society of Mechanical Engineering with about 40,000 members. Other large associations include the Japan Society of Civil Engineers (26,212 members), the Institute of Electrical Engineers (19,734), Institute of Electronics and Communication Engineers (26,565) and the Japan Surgical Society (19,596).

The Mechanical Engineering Society publishes a *Journal*, *Transactions* and *Bulletin*, conducts international conferences and invites foreign scientists to Japan. As a matter of fact, most of the societies here organize seminars and conferences and publish journals. Many thousands of Japanese journals are published, but one of the obvious difficulties of reporting activities in Japan is coping with the language barrier.

- English-Language Information Sources

A recent estimate of Japanese journals tallied more than 5000 and stated that only about 19% were listed in English-language abstracting services. Since most Japanese read and speak English, one might say that Japan sees the United States with 20-20 vision while the view of Japan from the United States is decidedly cloudy! Fortunately, there is a modest resource of English-language literature, particularly in the high technology areas where there are a number of good reference and news services, especially in basic materials related areas. Using these sources, it is possible to gather a great deal of information without being in Japan. Of course, being on the scene aids verifying data and establishing the necessary contacts to fully utilize the technology base. For the benefit of the reader, the appendix lists some typical information sources and points of contact for the selected sources. As far as more detailed information, Japan has many information research services, with both Japanese and foreign employees. For instance, the appendix lists the Yano and Sumika technical research services, but there are many other possibilities. It is worth noting that much of the information presented in the various media listed in the appendix is repetitive. Regardless of duplication, however, it is important to seek a wide variety of input rather than select a single excellent source. Obviously this is especially important for newcomers who must develop their own tailored and useful communications networks. Of course, the various government agencies and ministries, the trade organizations, industries, and universities also provide English-language information. Government "white papers" and annual agency summaries are also useful. Regarding the appendix, I apologize for any significant omissions as the listing is meant to be suggestive rather than complete. (Note that due to rapid yen value escalation, the subscription prices are out of date!)

- American Chamber of Commerce in Japan

Regarding useful contacts, I emphasize the fine work of the American Chamber of Commerce in Japan (ACCJ). This organization has many active committees and their *Journal* provides much valuable information. The April edition presented numerous informative articles on a wide range of topics. Several topics of particular interest to me included: "On-Line Information Sources-Data Bases in Japan," and "How to Monitor High Tech in Japan." I was heartened to learn of the strength and activities of ACCJ. Their membership rolls show over 1600 individual businessmen representing over 600 companies. About one-third of the members are non-Americans working for American firms. Insights and information provided by ACCJ are of much practical use to the typical business organization and ACCJ plays an important coordinating role. Frequently they have top-notch speakers at their various committees.

TYPICAL INFORMATION RETRIEVED

Let us consider typical information retrieved from some of the sources listed in the appendix. The March issue of *Techno Japan* reports the following items related to ceramics and materials science.

Chubu Electric Power Company, Ltd., is using an acoustic duct-lining material composed of aluminum and silicon oxide sintered at 1300°C to form a porous ceramic. While equivalent in some respects to such conventional materials as rock and glass wool in sound absorption capability, it is about five times as expensive, costing about 45 million yen for the Shin-Nagoya Power Plant. However, replacement and maintenance costs are expected to be considerably reduced since this material is able to survive under pressures of 176 kg/cm² at 500°C. The plant noise level has been reduced by 20% to about 60 dB levels. Several types of molding materials were described. Hitachi, Ltd., reported two types of novel mold materials which disintegrate on contact with either moisture or heat. The water sensitive type is based on alumina or silica powder with binders such as polyvinyl alcohol or potassium carbonate. The temperature sensitive type is of gypsum and a powdered pulp. Both are usable for slip casting. Maruju Kyogo Company, Ltd., has developed a so-called zero-pressure molding process to produce high-density alumina refractories. The Government Industrial Research Institute (GIRI), Kyushu, reports a ceramic composite of molybdenum silicide and titanium diboride offering unique electrical conductivity, strength, and oxidation resistance. Currently, molybdenum silicide is being produced under licensed patents from West Germany and Sweden and is used in heating appliances. Thermal printers normally use tantalum nitride or rubium oxide, and these must be protected by coatings due to their wear resistance characteristics. Nippon Tungsten Company, Ltd., described their conductive zirconia-based ceramic. Electrical conductivity was enhanced by adding about 30% carbide to the zirconia base. Hardness, thermal conductivity, and expansion coefficient were also changed significantly. Products under consideration include complex machine parts, dies and nozzles, decorative parts, VTR guard rollers, antistatic materials, wear-resistant, and electron discharge materials. Koransha Company, Ltd., and Professor K. Morinaga have produced sintered boron nitride at atmospheric pressures. More than 150 possible sintering aids were tested in the development. Their material can be slip cast into complex parts, is 97% pure, has density of 1.8 g/cm³, with bending strength of 9 kg/mm², thermal conductivity of 0.05 K cal/m/hr°C, and thermal expansion coefficient of 2.5. The producers cite usage temperatures as high as 2500°C under inert atmospheres and up to 1000°C for oxidative atmospheres. An interesting development was reported by Mitsui Seiki Company, Ltd., who now sell a machining center with a main shaft supported by silicon nitride angular contact

ball bearings, supplied by the NTN Toyo Bearing Company, Ltd. The bearings have a dn value of 1.6×10^{-6} , or more. Two machine types are available: HS 5A (horizontal) and VS 5A (vertical), priced at 45 and 35 million yen, respectively. The company expects to sell about 600 machines annually. Meanwhile, the bearing manufacturer hopes to develop a market of about 500 million yen per year for ceramics in machine tools, semiconductor production equipment and other devices. *Techno Japan* also contained a half-dozen feature and tutorial articles of general technological interest.

Another publication to consider is the quarterly issue of *Science and Technology in Japan*. An interesting aspect of this journal is the "Research Institute News," which profile various institutes and research centers on a regular basis, thereby providing a valuable reference file on government, university and industrial activities and capabilities. In the Oct-Dec 1985 issue, two informative surveys were described; one on the supply of high tech researchers and the other on trends in basic research directed towards innovative technology. The former survey was based on a questionnaire distributed to about 6400 people (research administrators, and researchers) at 1600 organizations (900 industrial enterprises, 500 universities and 150 national experimental laboratories). Response rate was about 30%. A number of problem areas were identified, and provocative facts from the survey were disclosed. The average age of industrial researchers was 35 years, while that at universities and national labs was 42.9 years. The age distribution patterns were also quite different. In private research bodies, the 25-29 year-old age group was largest, where 79% of researchers are under 35 years of age. In universities, the 35-39 year-old age group was largest and the 40-44 and 50-54 year-old age group was largest in the national labs. Two special problems cited were shortages of researchers in various high tech fields, and the extremely small movement of human resources outside their companies.

The *Japan Industrial and Technological Bulletin* of JETRO covers a wide range of subjects and their summaries are usually several paragraphs in length, mixed in with articles several pages long. Their September 1985 edition contained an article concerning use of chrome carbide ceramics for skid buttons. This ceramic was jointly developed by Kubota, Ltd., with Oita Steel Works (Nippon Steel Corporation) and Nippon Tungsten Company, Ltd. The chrome carbide skid buttons are used in continuous heating furnaces at steel works. Supposedly those composed of silicon nitride or silicon carbide can only be heated to 1100°C while this new chrome carbide is stable at 1300°C with no affinity for scales. The companies consider the new material suitable for numerous hot and acidic working environments.

Techgram Japan also discusses many topics, and they typically use a paragraph per item. Their 51-page-long April 1986 edition contained many briefs of interest to the materials community. One very useful feature of this journal is an index of companies cited, with addresses and phone numbers arranged alphabetically. Some items which drew my attention were the following. Makino Iron Works are marketing three types of fine ceramic tumbling mills which are constructed of alumina or zirconia. DPC Electronics Corporation and Osaka Diamond Industrial Company, Ltd., are jointly marketing an ultrasonic grinding machine using a diamond metal bonded grindstone. Supposedly their product permits 5 to 10 times higher grinding speeds compared with conventional machines. Oikawa Riken Company, Ltd., is marketing fine polishing tools for advanced ceramics materials. In this development, diamond grains are incorporated into melt spun nylon brush. Long lives and flexibility are the characteristics proclaimed for these tools. Tokuyama Soda Company, Ltd., and Tokyo Institute of Technology and the University of Chiba have developed an aluminum nitride which features bending strengths of about 30 kg/mm², and thermal conductivity about five times that of alumina. Kurosaki

Refractories Company, Ltd., is producing commercial quantities of its silicon nitride-silicon carbide ceramic. Their three varieties will be placed into burner chips, high-temperature blowing pipes of steel mills and in aluminum melting crucibles. Tokai Industrial Company, Ltd., reports an abrasion resistant zirconia ceramic bead 5 to 6 mm in diameter, suitable for use in ball mills. Sumitomo Metal Industries, Ltd., has developed composite ceramic skid buttons which have alumina particles of about 1 mm dispersed through out.

Considering the information just mentioned, it is evident that the English-language sources just mentioned provide much data on current products and accomplishments. Attempting to track basic research and scientific efforts, however, requires much additional effort, personal contacts and numerous other information sources than mentioned in this brief article.

APPENDIX

TYPICAL ENGLISH-LANGUAGE INFORMATION SOURCES

- ENGLISH-LANGUAGE NEWSPAPERS

Note that in this instance, coverage of high technology is usually limited to major developments, and generally only a small percentage of technologically important facts are reported.

Japan Times

Asian Wall Street Journal

Mainichi Daily News

Yomiuri Daily

Asahi Evening News

- ENGLISH WEEKLY TABLOIDS

These generally provide summaries of significant items of interest, and in some detail.

The Japan Economic Journal

Covers high tech news from the Japanese language *Nihon Keizai Shimbun* and *Nikkei Sangyo Shimbun*. For example, a recent twenty-page edition contained a few pages of technical articles. Contact: Annual subscription, \$99. 00, send check to OCS, America, Inc., P.O. Box 1654, Long Island City, NY 11101, Attn: JEJ Subscription Department.

Look Japan

For example, the twenty-eight-page April 10th edition contains about four pages of materials technology related news items. Contact: published by Look Japan, Ltd., 2-2, Kanda-Ogawamachi, Chiyoda-ku, Tokyo 101, Tel: (03) 291-8951, distributed by: Look Japan International, Ltd., 1626 Prince's Building, Chater Road, Hong Kong, Tel: 5-258015; annual subscription: \$50.00.

Dempa Digest

Typically about a dozen pages long, covering many news items in either a few sentences or a paragraph at a time. Contact: Dempa Publications, Inc., Sales Office, 400 Madison Avenue, New York, NY 10017, Tel: (212) 752-3003, Fax: (212) 752-3289, subscription: \$300. 00 per year.

Japan Chemical Week

A recent eight-page edition contained numerous summary articles of interest to the

ceramics community. Contact: Japan Chemical Week, The Chemical Daily Company, Ltd., International Division, 19-16, Shibaura 3-chome, Minato-ku, Tokyo, Tel: (03) 437-9530, Telex: 242-2362; annual subscription: \$369. 00.

- JOURNALS AND MAGAZINES

- . *Techgram Japan* published monthly, contains concentrated high tech news items. Contact: Nissho Iwai Corporation, New Venture Promotion Department, 4-5, Akasaka 2-chome, Minato-ku, Tokyo 107, Tel: (03) 588-3629; annual subscription \$280.00, translation and search services are available.
- . *Techno Japan* published monthly. Contact: Fuji Marketing Research Co., Ltd., 7th floor Daini Bunsei Building, 11-7, Toranomon 1-chome, Minato-ku, Tokyo 105, Tel: (03) 508-0051; annual subscription: surface mail, 34,000 yen.
- . *Science and Technology in Japan* published, quarterly. Contact: Maruzen Company, Ltd., P. O. Box 5050, Tokyo International 100-31.
- . *The Japan Industrial and Technological Bulletin*. Contact: Japan External Trade Organization, Machinery and Technology Department, 2-5, Toranomon 2-chome, Minato-ku, Tokyo 105, Tel: (03) 582-5511, Telex J24378.
- . *Bulletin of the Japan Society of Precision Engineering*. Contact: The Japan Society of Precision Engineering, Ceramics Building, 22-17, 2-chome, Hyakunin-cho, Shinjuku-ku, Tokyo, 160, Tel: (03) 362-4332; annual subscription: \$20.00.
- . *The Journal of the American Chamber of Commerce in Japan*, published 11 times a year. Contact: ACCJ, Fukide Building, No. 2, 4-1-21 Toranomon, Minato-ku, Tokyo 105, Telex: 123736 KYLETYO; annual subscription: 6,000 yen.

NEWSLETTERS, SEARCH AND RESEARCH SERVICES AND OTHER DATA BASES

- . *Japan High Tech Watcher*, written for the Western businessman, each week contains 40 to 50 brief summary news articles on the high tech materials industry. Annual subscription: \$595.00; to order, call (203) 325-2208.
- . *Ceramic Industry Japan*, a monthly newsletter on the Japanese ceramic industry. Contact: distributed by the Industrial Research Center of Japan, Inc., 202 Reedsdale Road, P.O. Box 356, Milton, MA 02186; annual subscription: \$300. 00.
- . *Nikkei High Tech Report*, twice a month this journal chronicles Japanese high technology for marketing, research and development, covering a wide range of topics. Contact: Subscriptions, U.S.A. JLS, Nikkei High Tech Report, P. O. Box 7236, Menlo Park, CA 94026; Tel: (415) 321-9832, facsimile: (415) 363-1169; annual subscription (24 issues), \$580. 00, or 158,000 yen.
- . *Japan English Publications in Print-1st Edition 1985-1987*; this data base attempts to list all English publications including books, magazines, and other types of publications from all Japanese and southeast Asian publishers. This edition has 8500 titles under 130 subjects, listed by publisher and author

cross-referenced by title. Special emphasis is placed on business and technical researchers. Contact: JEPP Editor, Japan Publications Guide Service, C.P.O. Box 971, Tokyo 100-91; Tel: (03) 667-9646.

- *Yano Research* provides up-to-date market and selected research and industrial topic studies. Contact: 2-10-1 Nihonbashi Hamacho, Chuo-Ku, Tokyo 103; Tel: (03) 667-9188, Telex: 2522278.
- *Sumika Technical Information Service, Inc.*, provides technical information and translation services. Contact: Sumika Technical Information Services, Inc., 8th Floor, Sumitomo Building, 15, 5-chome, Kitahama, Osaka, Japan.

CERAMIC TECHNOLOGY EVALUATION SERIES JAPAN FINE CERAMICS CENTER

Edward Mark Lenoe

OVERVIEW

KEY CERAMICS SOCIETIES

In the ceramics arena, there are several key societies. At least five organizations come immediately to mind. First, the Ceramic Society of Japan, which was founded in 1892, and has 16 branches throughout Japan, and membership of about 7000. Its publications include *Yogyo Kyokaishi* and *Seramikkusu*. Next the New Ceramics Discussion Group, established in June 1972. This group conducts meetings and seminars on ceramics, usually in the Kyoto-Osaka region and administers the Ministry of Education, Science and Culture project on "New Investigations of Functional Ceramics." There are the more recently initiated associations, such as the Engineering Research Association for High Performance Ceramics, which started in September 1981, and monitors MITI ceramics research for 15 companies and four research institutes in the Next Generation Basic Technology Research and Development Project. And there is the Japan Fine Ceramics Association, which was organized in July 1982, as well as the most recently established center of excellence, the Japan Fine Ceramics Center. Table I lists points of contact for these organizations.

Both the Japan Fine Ceramics Association and the Japan Fine Ceramics Center are truly exceptional institutions, and in certain respects they have no exact parallels in the United States. The Japan Fine Ceramics Association, headed by president Shinroku Saito, was founded with about 173 companies and now has around 200 members. The Association encompasses manufacturers from various industries such as refractory, chemical, fiber, steel, nonferrous, electric, machinery, car, heavy and light engineering as well as consumer organizations. The JFCA might be viewed as a trade association fostering the growth of the young fine ceramics industry, and to an extent, sponsoring research and development. The JFCA maintains a small office in Tokyo and sponsors many meetings, workshops and seminars. I will discuss these groups as well as other organizations, but in this article I concentrate on describing the Japan Fine Ceramics Center. The strength, wide interest and vitality of advanced ceramics technology in Japan is suggested by Figure 1, which illustrates the distribution of active companies across Japan. Obviously there is much to learn and much to report.

JAPAN FINE CERAMICS CENTER

Seiichi Tanaka, the chairman of the Chubu Economic Federation, was a prime mover for the establishment of the Japan Fine Ceramics Center. Tanaka promoted the establishment of JFCC, and in April 1984 a committee was established to develop plans and the organizational structure for the center. On 7 May 1985, the Japan Fine Ceramics Center was formally established, and on the 22nd of October 1985 a groundbreaking ceremony was held for the construction of a new center. I was fortunate to have the opportunity to visit the current office of the Japan Fine Ceramics center on several occasions and each time had cordial and informative meetings.

The new construction is slated for completion March 1987, and JFCC expects to

occupy their new quarters in April 1987. Initial staffing plans are for long-term growth to about 150 employees. Currently, the staff numbers about 40 which includes more than a dozen scientists. Regarding the current staff, there are a number of interesting observations. First of all, most of the staff are senior managers, engineers, or scientists and many are on multiyear loans from their parent organizations. Thus, JFCC has the benefit of highly experienced and influential personnel even though it is a new organization. Excellent examples of this are the president of JFCC, Masatoshi Morita and the managing director, Hiroshi Okuda. The Chubu area has 105 research facilities covering a wide variety of fields, and the level of industrial technology is quite high. Over 40% of Japan's automobiles come off assembly lines in this region! In the Chubu region, as far as the technological base for fine ceramics, many leading companies such as NGK Spark Plug, NGK Insulators, Noritake, Narumi Seito, Ibeden and Ishizuka Glass as well as the medium- and small-enterprises in the Tajimi and Seto areas are carrying out research and extensive development for further practical applications of fine ceramics. These companies currently account for about 60% of Japan's total production. Thus the JFCC has an excellent location from a variety of viewpoints, including access to industry, the large student body, and the numerous excellent research facilities.

MISSION, ORGANIZATION, FACILITIES AND FUNDING

I am indebted to Dr. Yoko Suyama, chief scientist of JFCC for indepth detailed information on the JFCC. The remainder of this discussion is largely based on several discussions and documentation which she so graciously provided to me.

- Organization

Now let us consider the center and its operation. The major objectives of the Japan Fine Ceramics Center are to contribute to the development and proliferation of fine ceramics, to popularize ceramics and promote the industry. This will be accomplished by basic and applied research in ceramics, by establishing test and evaluation methods and fostering their standardization, by actively promoting cooperation between appropriate universities, government and industrial organizations at national and local levels, by establishing the necessary technological and economic data base, by special efforts at developing international cooperation and by the education and training of promising individuals.

The JFCC organization is depicted in Figure 2.

- Funding

Funding for the center comes from numerous sources including local, national, and industrial contributions. Currently about 150 companies participate and their number is still growing! The contributions for small-size companies are about \$5000 while some large companies contribute about \$1,500,000! Figure 3 lists funding of JFCC.

- Current Major Activities

In spite of its small staff and relative infancy the center has a variety of active programs. The major activities are summarized in Figure 4 and are as follows:

Research and Development

Research and development related to new applications of fine ceramics.

Basic and applied research and development for manufacturing, machining, joining and design methods.

Establishment of Testing and Evaluation Methods

Development and standardization of and cooperation on testing and evaluation methods for mechanical properties of fine ceramics.

Execution of evaluation testing.

Establishment of Data Base

Establishment and distribution of data on fine ceramics and systems for their expanded use.

International Cooperation

Information exchange with foreign research organizations.

Personnel exchange with foreign research organizations.

Establishment of common data bases with foreign research organizations and their mutual use.

Undertaking of joint projects with foreign research organizations.

Education and training of promising individuals. (Guidance and aid for small and intermediate type industries, generally the companies nominate their own candidates.) The holding of symposiums, presentations, lectures and technical training sessions to educate and train promising individuals in technologies connected with fine ceramics.

Projects Supported by the Central Government

There are a number of projects at JFCC currently supported by the national government. Typically at JFCC these are one to two manyear levels of effort. Some of the current projects are tallied in Figure 5.

Development Project for the Next Generation of Atomic Energy Machinery and Equipment

This involves participation in the development of machinery, equipment and parts for a light-water reactor constructed under the Ministry of International Trade and Industry, (MITI), with the goal of more efficient operation. This nine-year program, which began in 1985, has a total funding of 12 billion yen.

Development of Corrosion Resistant Materials and Sealing Technologies

Participation in the development of oil pipe materials and sealing technologies for use in deep oil wells, conducted jointly with the Petroleum Corporation and the Metallic Materials R&D Center. This project has a six-year duration and total capital of 5.74 billion yen.

Survey of Fine Ceramics Industry Measures for 1985

To be carried out by JFCC under the auspices of MITI, surveys and research into data base systems for fine ceramics will be undertaken. Funds for this one-year project, starting in 1985--6.3 million yen.

Survey Foreign Testing and Evaluation Organizations for Fine Ceramics

To be carried out by JFCC under the auspices of the Fundamental Technology Research Promotion Center; a survey on the status and development trends in foreign testing and evaluation organizations of fine ceramics will be conducted. Funds for 1985, 4.0 million yen in total. Several additional projects are now in the planning stage.

- Facilities

As mentioned earlier, construction of the new facilities began in October 1985 and the first phase of the work is to be completed within fiscal 1986. The project schedule is for occupancy to commence in April 1987, with a projected staff of about 40 research personnel. Over the next ten-year period, that staff is anticipated to grow to 100 to 150 specialists. Current building facilities are described in Table 2. The site has an area of 18,000 m² (about four acres) and is located at 2-chome, Atsuta-ku, Nagoya, Aichi prefecture, in the Jin-gu Higashi and is about 200 m northeast of the Japan National Railways Atsuta Station.

JFCC MISSION ABROAD

The JFCC is quite serious about pursuing international cooperation. By way of example of this commitment, a team of experts traveled abroad the latter half of March 1986 on an introductory mission throughout North America and Europe. The activities and plans of JFCC were discussed by members of the mission with senior officials of the Ontario Research Foundation, the Army Materials Technology Laboratory, with Massachusetts Institute of Technology researchers as well as with scientists at the National Bureau of Standards, Oak Ridge National Laboratory, the American Ceramics Society headquarters, and Battelle Columbus Laboratories. In Great Britain, the National Physical Laboratory at Teddington and the British Ceramics Research Association were visited. The European visits included the École Nationale Supérieure de Céramique Industrielle, the DFVLR at Koln (Cologne) and the Joint Research Center at Petten. In addition to general descriptions of activities at JFCC, this mission presented results from their test method standardization program.

Standardization is an obvious area where international cooperation will make significant contributions. So far the JFCC has sponsored round robin testing in Japan, in flexure, tension and fracture toughness testing and the JFCC is systematically moving towards standardization of test methods in a variety of areas. JFCC hopes to develop cooperative projects in a variety of arenas. As their new facilities become available they also desire to attract top researchers from around the world. These visiting scientists would be offered access to world-class facilities and top level technician support.

Regarding the future of fine ceramics, in a recent interview reported in *Japan Chemical Week*, Masatoshi Morita, president of Japan Fine Ceramics Center, made the following remarks. "Fine ceramics have inexhaustible possibilities.... Every manufacturer is certainly showing great enthusiasm toward developing new materials. A few years ago,

some had the notion that a car with a fine ceramics engine would soon be on the market. However, at present, R&D efforts tend to be focused on practical experiments and we feel that ideas concerning the development of these materials are becoming realistic." As to the function of JFCC.... "We have a lot of tasks to tackle: R&D, promotion of evaluation tests and standardization, data banking, information services, development of small- and medium-sized enterprises and personnel training.... Fine ceramics are finding their usein various ways and the amount in use is also increasing.... Fine ceramics, like metals and high polymers, are a type of material, not an end product. They are used as a part of devices and machinery and being incorporated in one system, produce added value. Since they are used together with other materials, we have to work out some measures for comparing these materials. For this purpose, standardization is an essential measure. *Our foremost business is evaluation and standardization.*"

For some time now Japan's Ministry of International Trade and Industry (MITI), has been supportive of international standards on new ceramics. MITI looks to JFCC for expanding cooperation in every meaningful way. Another Japanese coordinator is MITI's Government Industrial Research Institute, Kyushu, which has interaction with the Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt (DFVLR), and with Swedish industry as well.

Regarding nonautomotive applications, it is of interest to note that oil/gas-drilling materials for deep wells are to be developed. Fourteen companies and Japan Fine Ceramics Center (JFCC) are to start a project aimed at developing appropriate technology for drilling oil and gas at high temperature and in a corrosive environment. The companies include Ishikawajima-Harima Heavy Industries, Nippon Steel, Sumitomo Electric Industry and Showa Denko. Technology to be developed includes low-cost tubing which resists corrosive gas and can be used for 7000 m deep wells, sealing technology for well heads and tubing connections, and finishing fluid which is chemically stable and does not corrode tubing material. Oil and gas are being drilled at greater and greater depths, consequently service temperatures are continuing to rise.

INTERNATIONAL FINE CERAMICS FAIR AND FORUM

An International Fine Ceramics Forum and Fair was held 5-7 March at the Nagoya Trade and Industry Center (Fukiage Hall) on the theme "Fine Ceramics and Man, Society and Culture." These events were jointly sponsored by the Japan Fine Ceramics Center (JFCC), the National Institute for Research Advancement (NIRA), Nagoya, and the Aichi prefecture government. The events also had the backing of the Ministry of International Trade and Industry as well as many technical and industrial organizations concerned with advanced ceramics.

Nagoya has been the site for several years now of an international fine ceramics fair. Each fair has succeeded in producing outstanding turnout, and this year's event was even more successful. The increased numbers of exhibitors continued to show impressive product expansion and their displays were impressive evidence of significant part scale-up and diversification, from the viewpoint of structural ceramics.

The International Forum featured European, North American, and Japanese experts in a variety of sessions encompassing lectures panel discussions, and audience participation was productive and enthusiastic. Keynote speakers described current status and future plans. We learned that fine ceramics had exceeded the various market projections and their gross sales continue to expand at an impressive rate. According to a survey

conducted by the Japan Fine Ceramics Association, the industry is growing far more rapidly than expected. Sales of fine ceramics raw materials (powder) in fiscal 1985 was estimated at \$326 million, an increase of 40% over 1984. The market figures reported by the Japan Fine Ceramics Association are listed in Table III. At the International Forum, Yoshihiro Adachi, director of the MITI Fine Ceramics Office, presented up-to-date data which showed that the 1985 projections had been surpassed.

A wide range of subjects were discussed by the participants and many tasks were directed towards, and appeals for aid made, to the JFCC. It was obvious that much is expected of this Center by government, universities and both large and small companies. To properly document all the dialog that occurred would require a special edition of this *Bulletin*!

In addition to the Exhibit Hall, special displays were made at a near by major department store. These, too, were of high quality and drew large and enthusiastic crowds. One booth for instance had a bank of video screens playing back detailed scanning electron microscopy studies with explanations of the observations.

- Issues for the Advanced Ceramics Industry

In a 1983 feature report published in the *Journal of Japanese Trade and Industry*, Frank Press, then president of the U.S. National Academy of Science and formerly science advisor to President Jimmy Carter, made the following observations. "Only the naive would be surprised at the trade frictions between Japan and the United States. Both countries believe in high technology as a pillar of their economic futures. Both are intensely competitive. Both face economic stresses. Both are competing for virtually the same markets, including...[one of] the world's largest technological markets--the United States itself."

Frank Press wrote optimistically of the U. S. response to the confrontation in high technology arenas, including what is a clear weakness in U.S. technology, namely manufacturing technology. As the dollar approaches the 150 yen level, emotional responses to trade considerations have continued to intensify. While it is impossible to thoroughly discuss such a complex problem in a few paragraphs, I think it is worthwhile to share some viewpoints, and to present some impressions related to advanced materials technology.

In terms of basic issues for the advancement of the fine ceramics industry, such issues can be viewed in a variety of ways, including local versus national and international, or from technological, industrial, university or government perspectives. Basic technological issues are listed in Table IV and relate to the fact that advanced ceramics are still a relatively immature technology, and their production is knowledge intensive.

For a moment, relating to shortage of qualified personnel, let's consider the training of scientists. On that subject in an April 28 news article titled "Engineers for Export," Daniel S. Greenberg made the following observations; "American universities continue to produce well trained engineers. But increasingly, the students who stay for the most advanced training are foreigners, many of them sent by their governments or industrial employers to soak up the best we have to offer. Last year, foreign students received a record 41% of the engineering Ph.Ds awarded by American universities. (Note: some university engineering department report graduate student populations with three quarters being foreign students!) They also received 27% of the masters degrees.... In mathematics, foreigners received 232 of the 699 doctorates awarded in the United States

in 1984. Foreign students in American engineering schools have at least one good reason to feel at home--about half the professors in our engineering schools are foreign citizens. ...Without these foreign faculty members, engineering education would be experiencing disaster, rather than the severe shortages that now confront it...[in addition].. Last year, according to a survey by the National Science Foundation, foreigners accounted for one-third of the scientists and engineers hired by Silicon Valley electronic firms.... Bless the foreigners.... But that still leaves troublesome questions: ...Where are the American engineers?" One can conjecture that advanced degrees have lost their allure for American youth. This is obviously not true in many other nations. Here in Japan, the training not only of college students, but the life-long training and education of employees receives very high levels of corporate attention. I have been told that here the company-sponsored short courses and advanced degree level training are particularly important for professional development. In the ceramics areas, it is my definite impression that far more engineers and scientists are diligently laboring on many important technological problems than in the United States.

It is interesting to compare national perspectives and assessments. Let's consider how Japanese businesses rate their technical competence against their U.S counterparts. In January 1985, the Japan Economic Planning Agency conducted a survey of Japanese corporations whose stocks are listed in the Tokyo Exchange, to find how they rate their technical competence compared to U.S. businesses. The survey went to 1623 corporations and a 71% response rate resulted. Figure 6 summarizes the findings. There is no doubt that executives of big Japanese businesses have confidence in their technical competence, and indeed some feel they are superior in industrial technology to their U.S. counterparts. The five-year trend from 1980 to 1985, as well as the future estimate for 1990, are of particular interest. Note that 24.9% of the executives thought the Japanese technology was inferior five years ago, while only 10.9% think that is the case today. Finally, only 5.1% think that U.S. businesses will have technical superiority five years from now!

Last summer a select group of U.S. government, academic and industrial experts met for several days to compare their views of Japanese technology. Their assessment was in terms of strengths and limitations and they also conjectured as to the relative equivalence of ceramics technology. Table 5 lists their summary conclusions. It is interesting to note they believe that Japan has the lead in many areas.

In recent years, the U.S. government has supported twice as much research and development as Japan, but 70% of the U.S. investment goes toward limited market defense applications. Part of the reason for the Japanese trade success is their high nondefense R&D investment aimed at the industrial market place. Noboru Makino, chairman of the Mitsubishi Research Institute, in a recent newspaper interview, had some interesting observations. "Americans go overboard on research...[and generally] disparage the hard work and patience needed to find practical applications.... U.S. firms continue to relocate manufacturing operations overseas...they [tend to] neglect the practical application of new ideas and inventions." Many average citizens in Japan feel their nation is unfairly blamed for the export imbalance!

There is no doubt that Japanese corporations and government officials truly understand the enormous importance of advanced materials, instrumentation and electronics and how these technologies are redefining the international marketplace; they know, too, that manufacturing automation, artificial intelligence, and robotics are totally reshaping the manufacturing process. And furthermore, corporations are aggressively capitalizing to pursue the commercial marketplace. By way of example, a single major

Japanese ceramics producer reports having 15 furnaces for manufacturing silicon nitride and silicon carbide. This includes one hot isostatic pressing (HIP) unit with a working zone of 500 x 1000 mm, capable of handling 150 automotive engine turbochargers at a charge! In the past dozen years, the number of HIP units in Japan has risen from a half-dozen to over 80. I am told that about 20 of these are for fine ceramics processing.

American industry is indeed being out capitalized, and it is also being out worked by some of the world's finest business men, engineers and scientists. Sixty to seventy hour work weeks, with many unreimbursed evenings and weekends are typical for many of my Japanese colleagues.

America has yet to acknowledge the internationalization of technology. It may well be that the era of total U.S. preeminence in technology has ended. Some key questions are: Can America stop its tide of deindustrialization? Will the U.S. commit the necessary capital and manpower to dominate the advanced materials areas? Can American cities, states and federal agencies work together more effectively? In general, the average American knows little about Japanese high technology and is unaware of their enormous impact on society. Regarding ceramics technology, it is important that we pursue international cooperation. The United States must increase its understanding of Japanese modes, increase exchanges in science and technology and continue to establish joint ventures. There are a number of areas for mutually beneficial activity, as listed in Table 6.

CONCLUSIONS

Although I have been in Japan for only a short time, I have learned many interesting facts. I am much impressed not only with the accomplishments of Japanese technology but also I am impressed with its spirit. And I am especially impressed to learn of the everyday importance of advanced materials throughout the Japanese culture. Because of this nation's capabilities and accomplishments there is no doubt that Japan has an excellent opportunity to accept a position of leadership in fine ceramics technology!

This Nagoya Fine Ceramics Forum allowed a free, open and detailed interdisciplinary discussion of important issues, and this was most impressive to me. Also impressive was the record of increasing ceramic market size, as reported earlier by Dr. Saito and Mr. Adachi from MITI. It was heartening to hear of the more rapid growth of the fine ceramics market than previously estimated.

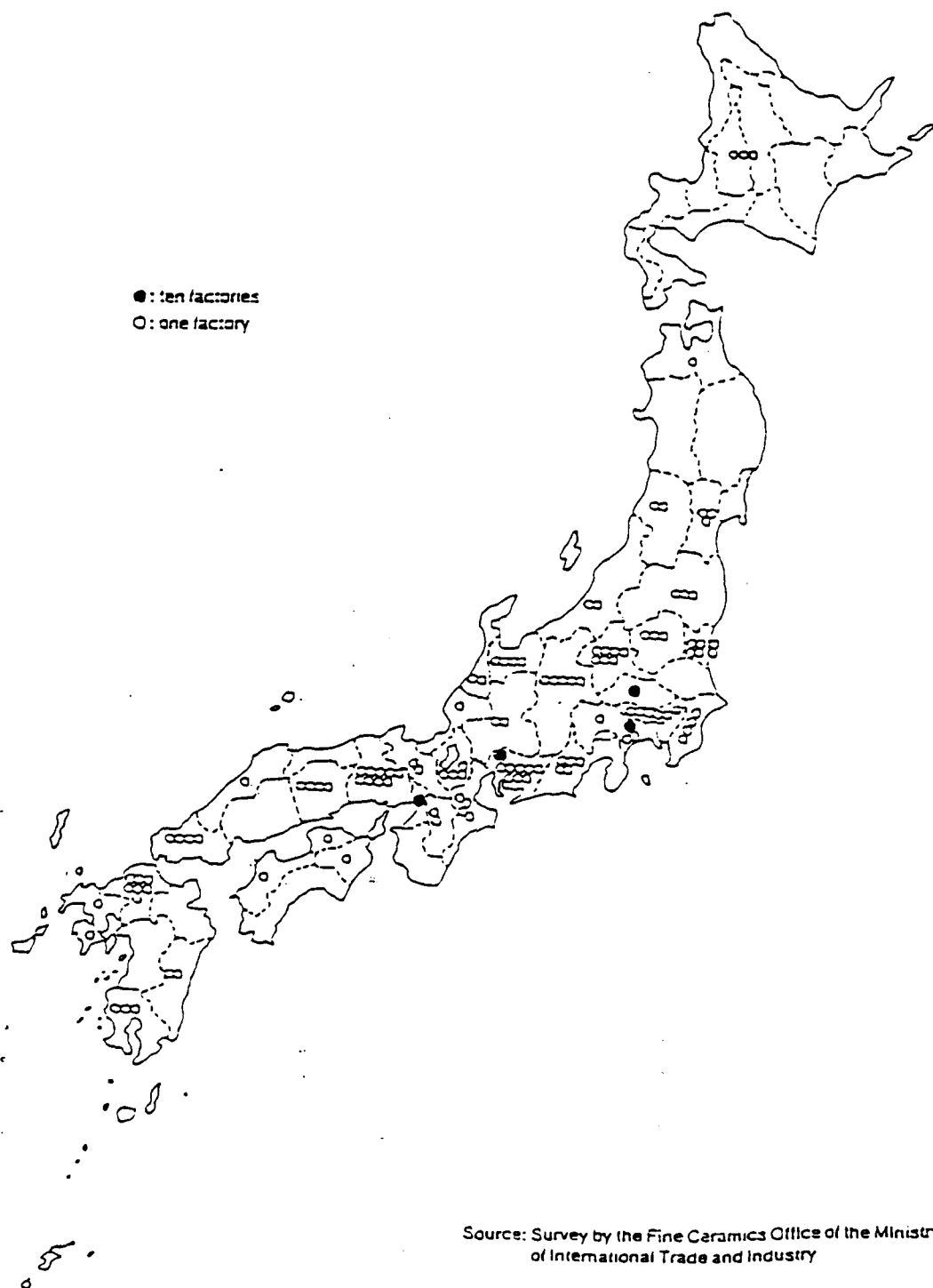


Figure 1. Distribution of Active Fine Ceramics Companies

ORGANIZATION OF THE FINE CERAMICS CENTER

PRESIDENT

DIRECTORS

RESEARCH & DEVELOPMENT LAB

SECRETARIAT

PHYSICAL PROPERTIES RESEARCH GROUP

INFORMATION & PUBLIC RELATIONS DEPARTMENT

CHEMICAL PROPERTIES RESEARCH GROUP

SALES & CONSULTATION DEPARTMENT

MECHANICAL PROPERTIES RESEARCH GROUP

CLERICAL DEPARTMENT

MANUFACTURING & PROCESSING RESEARCH GROUP

INFORMATION RESEARCH SERVICE

Figure 2.

CAPITAL

Donations by Economic Organizations	\$29.5 million
Subsidies & Local Government Donations	\$23.0 million
Subsidies by Public Organizations	\$2.5million

TOTAL \$55 million (11.0 billion yen)

Figure 3.

MAJOR ACTIVITIES

RESEARCH & DEVELOPMENT

- R&D for New Applications
 - Basic & Applied R&D for Powders, Manufacturing,
 - Machining, Joining, Design, etc.

ESTABLISHMENT of EVALUATION TESTING METHODS

- Development & Standardization of Evaluation Testing Methods, Mechanical Properties & Characterization
- Execution of Evaluation Testing

ESTABLISHMENT of DATA BASE

- Establishment & Utilization of Data Base

INTERNATIONAL COOPERATION

- Establish Common Data Bases
 - Researcher Exchanges
 - Information Exchange
 - Joint Projects

EDUCATION & TRAINING

- Conducting Symposiums, Lectures, Technical Training,
- Providing Guidance & Aid to Small & Intermediate Size Industries

Figure 4.

JAPANESE GOVERNMENT PROJECTS

DEVELOPMENT of NEXT GENERATION ATOMIC ENERGY EQUIPMENT

9-year project began 1985-total budget \$60 million

DEVELOPMENT OF CORROSION-RESISTANT MATERIALS & SEALING TECHNOLOGIES

6-year project began 1985 total budget - \$28.7 million

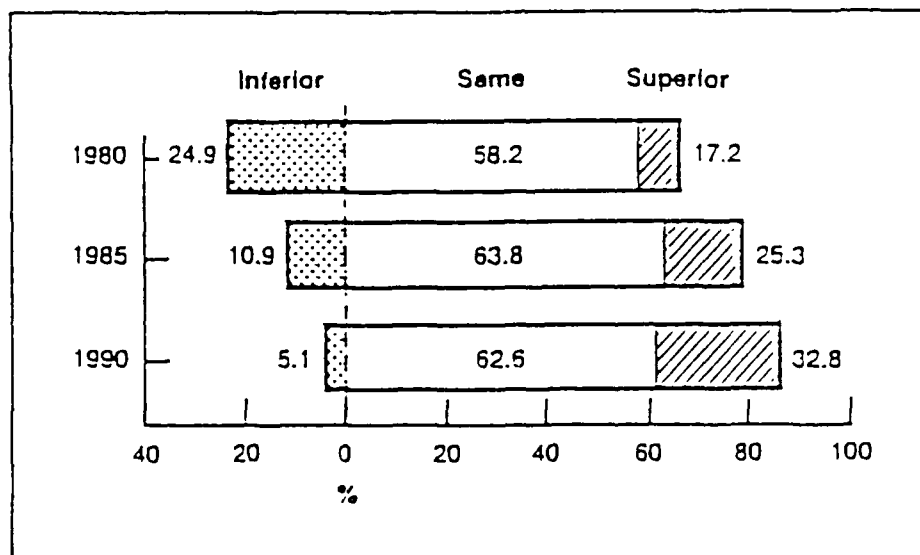
SURVEY OF FINE CERAMICS INDUSTRY

1-year project \$31,500

SURVEY OF FOREIGN EVALUATION TESTING

1985 budget \$20,000

Figure 5. Projects Supported by the Central Government.



How does the technical competence of Japanese businesses compare to that of U.S. businesses?

Source: Economic Planning Agency January 1985

Figure 6.

TABLE I

SOME KEY CERAMICS RELATED SOCIETIES IN JAPAN

CERAMIC SOCIETY OF JAPAN: Established 1892

Address: Shinjuku-ku, Hyakunin-cho 2-22-17, Tokyo 160
Phone: (03) 362-5231

JAPAN FINE CERAMICS ASSOCIATION: Established July 1982

Address: Minato-ku, Toranomon 1-22-13, Nishikan-Toranomon Building, 6th Floor,
Tokyo 105
Phone: (03) 508-8461

ENGINEERING RESEARCH ASSOCIATION FOR HIGH PERFORMANCE CERAMICS:
Established September 1981

Address: Minato-ku, Toranomon 1-81-1, Mori Building 10, 8th Floor, Tokyo 105
Phone: (03) 595-2472

NEW CERAMICS DISCUSSION GROUP: Established June 1972

Address: Dr. Mitsue Koizumi, Institute of Scientific and Industrial Research,
Osaka University, 8-1 Mihogaoka, Ibaraki, Osaka 567
Phone: (06) 887-5111

JAPAN FINE CERAMICS CENTER: Established May 1985

Address: 10th Floor, Nagoya Sakae Building
5-1 Buhei-Cho, Higashi-Ku, Nagoya 461
Phone: (052) 962-6048

TABLE II
BUILDING 1st PHASE

BUILDING	FLOOR AREA
Research and Development Laboratories	Five Stories 7,993
Manufacturing Processing Building	Two Stories 1,120
Office and Exhibition Hall	Two Stories 1,698
Incidental Facilities	68
Total 10,878 Square Meters Four-Acre Site Area	

TABLE III
PRODUCTION OF FINE CERAMICS PARTS AND MATERIALS (\$ millions)

	Electro- magnetic	Mechanical	Chemical/ medical	Thermal	Optical	Others	Total
1983	\$2,420.7	\$164.6	\$125.7	\$112.2	\$73.0	\$36.3	\$2,932.5
1984	\$3,050.2	\$214.3	\$157.0	\$154.01	\$87.3	\$46.0	\$3,708.9
1985 est.	\$3,622.8	\$244.7	\$194.4	\$197.5	\$96.6	\$73.8	\$4,394.5

TABLE IV
BASIC TECHNOLOGICAL ISSUES

RELATIVELY IMMATURE TECHNOLOGY

Poor part yield	Many newly emerging materials	
Lack of reproducibility	Stiff competition	
Need for standardization	Lower costs	Market development
	Improved production rates	Design procedures
	Low cost quality assurance methods	

KNOWLEDGE INTENSIVE INDUSTRY

Shortage of qualified personnell

TABLE V
ASSESSMENT BY SELECT U.S. COMMITTEE

JAPANESE FINE CERAMICS TECHNOLOGY

Strengths

- Broad Industrial Base
- National Thrust in Ceramics--Long-Range Plans
- High Degree of Coordination and Interaction
- High Quality by Control of Raw Material and Processing
- Multiyear Funding of R&D

Limitations

- University Research
- Micro Mechanics/Mechanical Behavior

AREA	LEADING NATION
Cutting Tools	Japan leads U.S.
Automotive Components	Leads U.S.
Energy Applications	Leads U.S.
Bio-Implants	Leads U.S.
Machining and Polishing	Leads U.S.
Mechanical Design	Lags U.S.
Research	Lags U.S.
Net Shape Fabrication	??
Joining	??
Powders	Japan lags U.S., but improving rapidly

TABLE VI
MUTUALLY BENEFICIAL AREAS OF COOPERATION

- Establishment of Common Standards of Performance, Testing and Composition
- Improvement of Availability of Published Literature on High Technology Ceramics
- Accumulation and Publication of Economic Data in Mutually Consistent Terms
- Enhancement of Interaction Between U.S. and Japanese Ceramics and Ceramic Engineering Societies
- Establishment and Fostering of Individual Researcher Interactions

INTERNATIONAL MEETINGS IN THE FAR EAST

1986-1990

Compiled by Yuko Ushino

The Australian Academy of Science, the Japan Convention Bureau, and the Science Council of Japan are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

1986

Date	Title, Attendance	Site	For information, contact
August 1	The 4th International Conference on Magnetic Fluids, Sendai Forum 16-F30-J100	Sendai, Japan	Secretariat of Sendai Forum c/o Institute of High-Speed Mechanics, Tohoku University 2-1-1 Katahira, Sendai City, Miyagi 980
August 3-7	The 20th Congress of the inter- national Association of Logopedics and Phoniatrics 45-F300-J500	Tokyo, Japan	Japan Society of Logopedics and Phoniatrics c/o Research Institute of Logopedics and Phoniatrics, Faculty of Medicine, Tokyo University 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
August 11-15	The 4th International Kimberlite Conference	Perth, Australia	Dr. A. F. Trendall, Director, Geological Survey of WA 66 Adelaide Terrace, Perth, WA 6000
August 17-22	The 7th International Zeolite Conference 20-F150-J350	Tokyo, Japan	Dr. H. Tominaga, Department of Synthetic Chemistry, Faculty of Engineering, Tokyo University 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
August 18-21	The 2nd SPSJ (The Society of Polymer Science, Japan) Inter- national Polymer Conference 15-F100-J400	Tokyo, Japan	The Society of Polymer Science, Japan 5-12-8 Ginza, Chuo-ku, Tokyo 104

*Note: Data format was taken from the Japan International Congress Calendar published by the Japan Convention Bureau.
No. of participating countries
F: No. of overseas participants
J: No. of Japanese participants

1986

Date	Title, Attendance	Site	For information, contact
August 20-22	1986 International Conference on Solid State Devices and Materials 20-F200-J800	Tokyo, Japan	Organizing Committee of Conference on Solid State Devices and Materials c/o Business Center for Academic Societies, Japan 2-4-16 Yayoi, Bunkyo-ku, Tokyo 113
August 20-23	1986 INS International Symposium on Hypernuclear Physics	Tokyo, Japan	Dr. Kengo Ogawa, Institute for Nuclear Study, University of Tokyo 3-2-1 Midori-cho, Tanashi-City, Tokyo 188
August 24-29	The 8th IUPAC Conference on Physical Organic Chemistry 38-F250-J570	Tokyo, Japan	Dr. Minoru Hirota, Secretary General, The 8th IUPAC Conference on Physical Organic Chemistry c/o Chemical Society of Japan 1-5 Kanda-Surugadai, Chiyoda-ku, Tokyo 101
August 24-29	The 5th International IFAC Symposium on Automation in Mining, Mineral and Metal Processing 40-F100-J200	Tokyo, Japan	Society of Instrument and Control Engineers 1-35-28-303 Hongo, Bunkyo-ku, Tokyo 113
August 24-30	The 6th International Congress of Parasitology	Brisbane, Australia	Secretariat: Australian Academy of Science GPO Box 783, Canberra, ACT 2601
August 25-28	The 12th International Conference on Very Large Data Bases 30-F100-J300	Kyoto, Japan	Dr. Setsuo Osuga, Institute of Interdisciplinary Research, Faculty of Engineering, Tokyo University 4-6-1 Komaba, Meguro-ku, Tokyo 153
August 25-29	The 10th International Conference on Atomic Physics 25-F250-J150	Tokyo, Japan	Institute of Physical and Chemical Research 21 Hirosawa, Wako City, Saitama 351-01
August 25-29	The 12th International Sedi- mentological Congress	Canberra, Australia	Australian Convention and Travel Services GPO Box 1929, Canberra, ACT 2601

Date	Title, Attendance	Site	For information, contact
August 25-29	The 7th International Union of Air Pollution Prevention Associations Congress	Sydney, Australia	R. W. Manuell, Seretary, Clean Air Society of Australia and New Zealand P.O. Box 191, Eastwood, NSW 2122
August 25-30	The 11th International Conference on Few-Body Systems in Particle and Nuclear Physics 25-F150-J100	Tokyo and Sendai, Japan	Department of Physics, Tohoku University Aoba, Aramaki, Sendai 980
August 26-30	International Conference on Martensitic Transformations (ICOMAT-86) 30-F150-J150	Nara, Japan	Conference Secretariat, ICOMAT-86, Japan Institute of Metals Aoba, Aramaki, Sendai 980
August 27-30	The 33rd Annual General Meeting of Genetics Society of Australia	Adelaide, Australia	Dr. D. E. A. Catcheside, School of Biological Sciences, Flinders University of SA Bedford Park, SA 5042
August 28-30	Rotating Machines Conference	Melbourne, Australia	The Conference Manager, The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
August 29	Sapporo Symposium on Biological Phythm N.A.-F30-J80	Sapporo, Japan	Physiology I, School of Medicine, Hokkaido University Nishi 7-chome, Kita 5-jo, Kita-ku, Sapporo 060
August 31- September 4	The Second International Symposium Foundations of Quantum Mechanics; In the Light of New Technology	Tokyo, Japan	Professor Mikio Namiki, Physics, School of Science and Engineering, Waseda University 3-4-1 Okubo, Shinjuku-ku, Tokyo 160

1986

Date	Title, Attendance	Site	For information, contact
August 31- September 7	The 11th International Congress on Electron Microscopy 55-F1,000-J2,000	Kyoto, Japan	Professor K. Ogawa, Department of Anatomy, Faculty of Medicine, Kyoto University Yoshida Konoe-cho, Sakyo-ku, Kyoto 606
September 1-2	International Symposium on Muon- Catalyzed Fusion (μ -CF'86)	Tokyo, Japan	Professor Kanetada Nagamine, Meson Science Laboratory, Faculty of Science, Tokyo University 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
September 1-5	The 3rd Asian Congress of Fluid Mechanics-IUTAN 12-F100-J150	Tokyo, Japan	Secretariat: The 3rd Asian Congress of Fluid Mechanics c/o Faculty of General Education, Tokyo University of Agriculture and Technology 3-5-8 Saiwaichi, Fuchu City, Tokyo 183
September 4-10	The International Symposium on Geomechanics	Beijing, People's Republic of China	Secretariate of International Symposium on Geomechanics, c/o The Institute of Geomechanics, Chinese Academy of Geological Sciences, Fahuasi, Xijiao, Beijing, People's Republic of China
September 9-11	The 3rd International Conference on Science and Technology: Zirconia 37-F250-J350	Tokyo, Japan	Ceramics Society of Japan 2-22-17 Hyakunincho, Shinjuku-ku, Tokyo 160
September 15-19	An International Symposium on Molecular Structure: Chemical Reactivity and Biological Activity	Beijing, People's Republic of China	Dr. Xu Xiao-Jie, Institute of Physical Chemistry, Peking University Beijing, People's Republic of China
September 18-19	International Advanced Materials Technology: Ceramic Workshop	Tokyo, Japan	Secretariat: International Congress Service, Inc. Kasho Building, 2-14-9 Nihonbashi, Chuo-ku, Tokyo 103

1986

Date	Title, Attendance	Site	For information, contact
September 21-25	World Congress of Chemical Engineering 35-F300-J1,000	Tokyo, Japan	Society of Chemical Engineers, Japan Kyoritsu Kaikan, 4-6-19 Honhinata, Bunkyo-ku, Tokyo 112
September 22-26	The 9th International Meeting of International Union of Phlebology 33-F200-J300	Kyoto, Japan	Secretariat: The 9th World Congress of Phlebology c/o Japan Convention Service, Inc. Nippon Press Center Building 2-2-1 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
September 25- October 1	The 7th International Congress of Eye Research 25-F450-J550	Nagoya, Japan	Professor Shuzo Iwata, Department of Biophysical Chemistry, Faculty of Pharmaceutical Science, Meijo University 15 Yagoto-Urayama, Tempaku-cho, Tempaku-ku, Nagoya 488
September 30- October 2	The 6th International Display Research Conference (Japan Display'86) 26-F200-J450	Tokyo, Japan	Secretariat: The 6th International Display'86 Research Conference c/o Japan Convention Services, Inc. Nippon Press Center Building, 2-2-1 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
September	The VIIth International Conference on Hyperfine Interactions	Bangalore, India	Professor L. Kerwin University of Javal Quebec, P Q Canada G1K 7p4, Canada
October 7-9	The 4th International Conference on Optical Fiber Sensors (OFS '86) 20-F150-J200	Tokyo, Japan	Secretariat: The 4th International Conference on Optical Fiber Sensors c/o Hikari Sangyo Gijutsu Shinko Kyokai, 20th Mori Building, 2-7-4 Nishi-Shinbashi, Minato-ku, Tokyo 105
October 7-14	International Symposium on Sea- level Changes and Applications (IGCP Project 200)	Quingdao, People's Republic of China	Zhao Songling, Acad Sinica Institute of Oceanography 7 Nanhai Road, Quingdao, People's Republic of China

1986

Date	Title, Attendance	Site	For information, contact
October 13-17	The 11th International Conference on Cyclotrons and Their Applications 21-F150-J150	Tokyo, Japan	Dr. Yasuo Hirao, Institute for Nuclear Study, University of Tokyo 3-2-1 Midori-cho, Tanashi, Tokyo 188
October 14-17	The 10th IEEE International Semiconductor Laser Conference 20-F150-J150	Kanazawa, Japan	Department of Electrical and Computer Engineer, Kanazawa University 2-40-20 Kodatsuno, Kanazawa 920
October 15-19	International Conference of Biotechnology BIO-JAPAN'86 15-F250-J550	Tokyo, Japan	The Japanese Association of Industrial Fermentation Bioindustry Development Center 7th Floor, Dowa Building, 5-10-5 Shimbashi, Minato-ku, Tokyo 105
October 21-24	The 8th International Acoustic Emission Symposium	Tokyo, Japan	The Japanese Society for Non-destructive Inspection 5-4-5 Asakusabashi, Taito-ku, Tokyo 111
November 4-7	CIE 1986 International Conference on Radar (CICR-86)	Shanghai, People's Republic of China	Mr. Zhou Wensheng, China Academy of Electronic Technology P.O. Box 134, Beijing
November 13-20	International Conference on Plasma Physics and Controlled Nuclear Fusion Research 40-F300-J300	Kyoto, Japan	Japan Atomic Energy Research Institute 2-2-2 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
November 19-22	TECHNO-OCEAN'86 International Symposium 12-F100-J300	Kobe, Japan	World Import Mart Company, Ltd. 3-1-3 Higashi-Ikebukuro, Toshima-ku, Tokyo 170
December 1-3	1986 International Symposium on Biological Sciences in Space	Nagoya, Japan	Professor T. Mano, Research Institute of Environmental Medicine, Nagoya University Furo-cho, Chikusa-ku, Nagoya 464

1987

Date	Title, Attendance	Site	For information, contact
February 22-27	The 6th Conference and Exhibition on Exploration Geophysics	Perth, Australia	Dr. F. Fritz C/-BP Minerals, 200 Adelaide Terrace, Perth, WA 6000
April 8-11	International Symposium on Physics of Magnetic Materials (ISPMM'87) 18-F50-J150	Sendai, Japan	Department of Applied Physics, Faculty of Engineering, Tohoku University Aoba, Aramaki, Sendai 980
April 14-17	The 25th International Magnetics Conference (INTERMAG'87) 32-F500-J1000	Tokyo, Japan	The Magnetics Society of Japan Kotohira Kaikan Building, 1-2-8 Toranomon, Minato-ku, Tokyo 105
April 20-22	International Symposium on Magnetism of Intermetallic Compounds 20-F100-J200	Kyoto, Japan	Department of Metal Science and Technology, Faculty of Engineering, Kyoto University Yoshida-Honmachi, Sakyo-ku, Kyoto 606
April 20-22	International Symposium on Magneto-Optics 10-F50-J150	Kyoto, Japan	NHK Science and Technical Research Laboratories 1-10-11 Kinuta, Setagaya-ku, Tokyo 157
April 20-24	The 11th Particles and Nuclei International Conference (PANIC'87) 40-F450-J450	Tokyo, Japan	Professor Koji Nakai, National Laboratory for High Energy Physics 1-1 Uehara, Oho-machi, Tsukuba-gun, Ibaraki 305
April 30- May 1	Australian Academy of Science-- Annual General Meeting	Canberra, Australia	Secretariat: Australian Academy of Science GPO Box 783, Canberra, ACT 2601
May 17-21	The 44th General Assembly of International Magnesium Association 15-F100-J100	Tokyo, Japan	Japan Light Metal Association, Nihombashi-Asahikaikan, 2-1-3 Nihombashi, Chuo-ku, Tokyo 103

1987

Date	Title, Attendance	Site	For information, contact
May 17-22	World Conference on Advanced Materials for Innovations in Energy, Transportation, and Communications	Tokyo, Japan	CHEMRAWN VI Coordinating Office, The Chemical Society of Japan 1-5 Kanga-Surugadai, Chiyoda-ku, Tokyo 101
May (Tentative)	Symposium for Quantitative Aspects of the Nitrogen Cycle	Brisbane, Australia	Dr. R. J. Myers, CSIRO Division of Tropical Crops and Pastures St Lucia, QLD 4067
June 2-5	Transducers '87 20-F200-J600	Tokyo, Japan	Secretariat: Transducer '87 c/o Sansei International Inc., Fukide No. 2 Building, 4-1-21 Toranomom, Minato-ku, Tokyo 105
June 8-12	1987 International Congress on Membranes and Membrane Processes (ICOM'87) 30-F200-J400	Tokyo, Japan	Institute of Industrial Science, University of Tokyo 7-22-1 Roppongi, Minato-ku, Tokyo 106
July 6-10	The Sixth International Conference on the Physics of Non-Crystalline Solids F70-J130	Kyoto, Japan	Professor F. Sakka, The Institute for Chemical Research, Kyoto University Gokanoshio, Uji-City, Kyoto 611
July 20-25	The Second IFSA (Italy, France Spain, America) Congress (2nd IFSA Congress)	Tokyo, Japan	Secretariat: The Second IFSA Congress c/o The Society of Instrument and Control Engineers, 1-35-28-303 Hongo, Bunkyo-ku, Tokyo 113
July 26-31	XXV International Conference on Coordination Chemistry	Nanjing, People's Republic of China	Professor Xiao-Zeng You, Coordination Chemistry Institute Nanjing, Jansu Province
Undecided	The International Conference on Computers In Chemical Research and Education (the ICCCRE)	Shanghai, People's Republic of China	Dr. Yongzheng Hui, Shanghai Institute of Organic Chemistry, Academia Sinica 345 Lingling Lu, Shanghai 200032

1987

Date	Title, Attendance	Site	For information, contact
August 12-20	The 14th International Congress of Crystallographers	Perth, Australia	Dr. E. N. Maslen, Centre for Crystallography, University of Western Australia WA 6009
August 17-21	1987 Luminescence International Conference	Beijing, People's Republic of China	Professor Xu Xurong, Chinese Society of Luminescence, Xinmin Street 13 Chang-chun, People's Republic of China
August 19-26	The 18th International Conference on Low Temperature Physics	Kyoto, Japan	Professor Shinji Ogawa, The Institute for Solid State Physics, Tokyo University 7-22-1 Roppongi, Minato-ku, Tokyo 106
August 24-27	The 7th International Conference On Quarks-Leptons Physics in Collision 15-F120-J80	Tsukuba, Japan	Organizing Committee: The 7th International Conference on Physics in Collision c/o National Laboratory for High Energy Physics, 1-1 Uehara, Ohomachi, Tsukuba-gun, Ibaraki 305
August 27-30	The 6th International Conference on Biomagnetism 20-F300-J500	Tokyo, Japan	Secretariat: The 6th International Conference on Biomagnetism c/o INTER Group, Akasaka Yamakatsu Building, 8-5-32 Akasaka, Minato-ku, Tokyo 197
August 31- September 4	The 8th International Symposium on Plasma Chemistry	Tokyo, Japan	Professor Kazuo Akashi, Metallurgy, Faculty of Engineering, University of Tokyo 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
August (tentative)	The 10th International Congress of Pharmacology	Sydney, Australia	Professor J. Shaw, Secretary, Interim Organising Committee, Department of Pharmacology, University of Sydney NSW 2006
August (tentative)	International Congress for Phar- macology, Satellite on Cardio- Active Drugs	Hayman Island, Australia	Australian Convention and Travel Services GPO Box 1929, Canberra, ACT 2601

1987

Date	Title, Attendance	Site	For information, contact
September 6-11	The Sixth Pacific Basin Conference	Beijing, People's Republic of	Dr. Chih Wang, 3110 Chintimini Drive, Corvallis, Oregon 97330, USA
September 16-18	International Symposium on Optical Memory	Tokyo, Japan	Optoelectronic Industry and Technology Development Association 5th Floor, No. 20 Mori Building, 2-7-4 Nishi-Shimbashi, Minato-ku, Tokyo 105
October 12-16	The 12th International Conference on Atomic Collisions in Solids	Okayama, Japan	Professor Fuminori Fujimoto, Physics Section, College of General Education, University of Tokyo 3-8-1 Komaba, Meguro-ku, Tokyo 153
October 18-24	International Towing Tank Conference (ITTC) 30-F100-J100	Kobe, Japan	Society of Naval Architects of Japan (SNAJ) Sempaku-Shinko Building, 8th Floor, 1-15-16 Toranomon, Minato-ku, Tokyo 105
October 20-23	International Conference on Quality Control--1987 Tokyo 45-F350-J400	Tokyo, Japan	Union of Japanese Scientists and Engineers 5-10-11 Sendagaya, Shibuya-ku, Tokyo 151
November 9-13	The 2nd International Conference on Refractories 6-F170-J270	Tokyo, Japan	Secretariat: The 2nd International Conference on Refractories c/o International Congress Service, Inc. Kasho Building, 2-14-9 Nihombashi, Chuo-ku, Tokyo 103
November 15-18	1987 Global Telecommunications Conference (GLOBECOM'87) 30-F500-J700	Tokyo, Japan	Secretariat: GLOBECOM'87 c/o KDD Research and Development Laboratories 2-1-23 Nakameguro, Meguro-ku, Tokyo 153

1988

Date	Title, Attendance	Site	For information, contact
January 28-31	Royal Australian Chemical Institute, Division of Inorganic Chemistry, National Meeting (COMO 13)	Melbourne, Australia	Dr. P. Tregloan, Department of Inorganic Chemistry, University of Melbourne Parkville, Victoria 3052

1988

Date	Title, Attendance	Site	For information, contact
February 22-26	Engineering Conference	Sydney, Australia	The Conference Manager, The Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600
April 10-12	The 4th International Conference on Aluminium Weldment 32-F100-J150	Tokyo, Japan	Japan Light Metal Welding and Construction Association (JLWA) Yura Building, 3-37-23 Kanda-Sakumacho, Chiyoda-ku, Tokyo 101
April 26- May 3	The 3rd World Biomaterials Conference 15-F500-J500	Kyoto, Japan	Japan Society for Biomaterials c/o Institute for Medical and Dental Engineering, Tokyo Medical and Dental University 2-3-10 Kanda-Surugadai, Chiyoda-ku, Tokyo 101
June 5-10	The 6th International Conference on Surface and Colloid Science	Hakone, Japan	Division of Colloid and Surface Chemistry, The Chemical Society of Japan 1-5 Kanda-Surugadai, Chiyoda-ku, Tokyo 101
July 1-12	The 16th International Congress of Photogrammetry and Remote Sensing 65-F1,000-J1,000	Kyoto, Japan	Japan Society of Photogrammetry 601 Daiichi Honan Building, 2-8-17 Minami-Ikebukuro, Toshima-ku, Tokyo 171
July 17-23	International Congress of Endocrinology N.A.-F1,500-J2,000	Kyoto, Japan	Japan Endocrine Society c/o Seirenkaikan Kyoto Furitsu Medical University Nishizume Konjinbashi, Kamigyo-ku, Kyoto 602
August 1-5	The 10th Congress of the Inter- national Ergonomics Association	Sydney, Australia	Ergonomics Society of Australia and New Zealand, Science Centre 35-43 Clarence Street, Sydney, NSW 2000
August 1-6	IUPAC 32nd International Symposium on Macromolecules 50-F500-J1,300	Kyoto, Japan	The Society of Polymer Science, Japan 5-12-8 Ginza, Chuo-ku, Tokyo 104

1988

Date	Title, Attendance	Site	For information, contact
August 15-19	The 3rd International Phyco- logical Congress	Melbourne, Australia	Dr. M. N. Clayton, Botany Department, Monash University Clayton, Victoria 3168
August 21-26	International Geographical Congress	Sydney, Australia	Secretariat: Australian Academy of Science GPO Box 783, Canberra, ACT 2601
November 19-26	The 13th International Diabetes Federation Congress	Sydney, Australia	Professor J. R. Turtle, Professor of Medicine Department of Endocrinology, University of Sydney NSW 2006

1989

Date	Title, Attendance	Site	For information, contact
August 13-18	Solar Energy Congress Tokyo 1989 40-F600-J400	Tokyo, Japan	Japanese Section of International Solar Energy Society 322 San Patio, 3-1-5 Takada-no-baba, Shinjuku-ku, Tokyo 160
1989 (tentative)	International Conference on Coordination Chemistry	Brisbane, Australia	Professor M.A. Bennett, Research School of Chemistry, ANU P.O. Box 4, Canberra, ACT 2601

1990

Date	Title, Attendance	Site	For information, contact
July (tentative)	The Xth International Congress of Nephrology 10-F1,000-J4,000	Osaka, Japan	Japanese Society of Nephrology c/o 2nd Department of Internal Medicine, School of Medicine, Nippon University 30-1 Oyaguchi-Kamicho, Itabashi-ku, Tokyo 173

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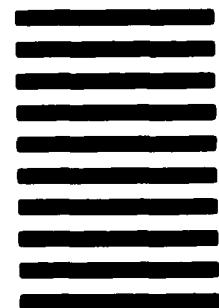
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